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Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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Chief Scientist

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a computer code for predicting atmospheric transmittance and the thermal radiation emitted by the atmosphere and earth from 350 to 40,000 cm^{-1} at a spectral resolution of 20 cm^{-1}. The program is based on the LOWTRAN 4 (1978) computer code. New altitude and relative-humidity dependent aerosol models and new fog models are included in the code. In addition, the new code structure consists of a main program and 19 subroutines.

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20. Abstract (Continued)

The computer code contains representative (geographical and seasonal) atmospheric models and representative aerosol models with an option to replace them with user-derived or measured values. The program can be run in one of two modes, namely, to compute only atmospheric transmittance or both atmospheric transmittance and radiance for any given slant path geometry.

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Preface

We wish to acknowledge the contributions made by Major Peter Soliz of the Air Force Avionics Laboratory and Major Vernon Bliss of the Foreign Technology Division to the further development of the LOWTRAN model through discussions, comments, and testing of the code presented in this report.

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Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5

1. INTRODUCTION

This report describes a Fortran computer code, LOWTRAN 5, designed to calculate atmospheric transmittance and radiance for a given atmospheric path at moderate spectral resolution. This code is an extension of the current LOWTRAN atmospheric code, LOWTRAN 4[1] (and its predecessors LOWTRAN 3B,[2] LOWTRAN 3,[3] and LOWTRAN 2[4]). All the options and capabilities of the LOWTRAN 4 code have been retained. New altitude and relative humidity dependent aerosol models and new fog models have been incorporated into LOWTRAN 5. In addition, extensive restructuring of the code into subroutines has been made for improved logical flow of the program and user understanding.

(Received for publication 20 February 1980)

1. Selby, J.E.A., Kneizys, F.X., Chetwynd Jr., J.H., and McClatchey, R.A. (1978) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4, AFGL-TR-78-0053, AD A058 643.
2. Selby, J.E.A., Shettle, E.P., and McClatchey, R.A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B, AFGL-TR-76-0258, AD A040 701.
3. Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255, AD A017 734.
4. Selby, J.E.A., and McClatchey, R.A. (1972) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 2, AFCRL-TR-72-0745, AD 763 721.

The LOWTRAN code calculates atmospheric transmittance and radiance, averaged over 20-cm^{-1} intervals in steps of 5 cm^{-1} from 350 to 40,000 cm^{-1} (0.25 to 28.5 μm). The code uses a single-parameter band model for molecular absorption, and includes the effects of continuum absorption, molecular scattering and aerosol extinction. Refraction and earth curvature are included in the calculation for slant atmospheric paths. The code contains representative atmospheric and aerosol models, and the option to replace them with user-derived or measured values.

In this report, the model atmospheres and the new aerosol models in the code are described in Sections 2 and 3. Following this is a discussion of the spherical geometry with refraction used in the program. In Sections 5 and 6, a detailed description of the calculation of atmospheric transmittance and radiance is given. The structure of the computer code is presented in Section 7, with a listing of the code in Appendix A and a definition of symbols used in the main program given in Appendix B. User instructions for the LOWTRAN code are given in Section 8. Examples of the output of the program and illustrations of transmittance and radiance spectra calculated from the code are presented in Sections 9 and 10. A comparison of the new LOWTRAN aerosol models with measurements is made in Section 11. In Section 12, an example of the sensitivity of the code to meteorological input parameters is given. Comments on the use and limitations of the code are given in the last section.

In Appendix C, a segmented loader map of the LOWTRAN code run on the AFGL CDC 6600 is given. A discussion of the method used in the program to calculate water vapor density, relative humidity, and dew-point temperature is contained in Appendix D.

An additional set of stratospheric water vapor profiles for use in LOWTRAN is described in Appendix E. In Appendix F, some previous LOWTRAN transmittance and radiance comparisons with measurements have been reprinted.

The LOWTRAN 5 code will be made available from the National Climatic Center, Federal Building, Asheville, NC 28801. It is requested that users receiving the code, remove cards LOW 320, 330 and 340 from the main program (see Appendix A) and keypunch their name, affiliation, and address on these cards. These cards will be used to update the AFGL LOWTRAN mailing list and for notification to users of changes in the code. They should be mailed to F. X. Kneizys, AFGL/OPI, Hanscom AFB, Bedford, MA 01731.

2. MODEL ATMOSPHERES

The altitude, pressure, temperature, water vapor density, and ozone density for the U.S. Standard atmosphere and five seasonal model atmospheres are provided as basic input data for LOWTRAN. The model atmospheres correspond to the 1962 U.S. Standard atmosphere[5] and the five supplementary models; that is, Tropical (15°N), Midlatitude Summer (45°N, July), Midlatitude Winter (45°N, January), Subarctic Summer (60°N, July), and Subarctic Winter (60°N, January). The different models are digitized in 1-km steps from 0 to 25 km, 5-km steps from 25 to 50 km, then at 70 km and 100 km directly as given by McClatchey et al.[6]

The water vapor and ozone altitude profiles added to the 1962 U.S. Standard atmosphere by McClatchey et al[6] were obtained from Sissenwine et al[7] and Hering et al[8] respectively, and correspond to mean annual values. The water vapor densities for the 1962 U.S. Standard atmosphere correspond to relative humidities of approximately 50 percent for altitudes up to 10 km, whereas the relative humidity values for the other supplementary models tend to decrease with altitude from approximately 80 percent at sea level to approximately 30 percent at 10-km altitude. The Sissenwine profiles are representative of "moist" stratospheric water vapor content. Alternative "dry" stratospheric water vapor profiles are provided in LOWTRAN using subroutine DRYSTR discussed in Appendix E.

The temperature profiles for the six model atmospheres as a function of altitude are shown in Figure 1. The pressure profiles are given in Figure 2. Figures 3a and 3b show the water vapor density vs altitude from 0 to 100 km, and an expanded profile from 0 to 30 km. Figures 4a and 4b and Figures 5a and 5b show similar profiles for ozone and for the uniformly mixed gases.

It is assumed in this report that mixing ratios of the gases, CO_2, N_2O, CH_4, CO, N_2, and O_2 remain constant at all altitudes at the following values: 330, 0.28, 1.6, 0.075, 7.905×10^5, and 2.095×10^5 parts per million respectively. These gases as a whole, with the exception of nitrogen, will be referred to as the uniformly mixed gases.

Measurements made from balloon flights[9], have shown the existence of nitric acid in the earth's atmosphere. Although nitric acid is of only minor importance in atmospheric transmittance calculations, it has been shown to be a significant source of stratospheric emission, particularly in the atmospheric window region from 10 to 12 μm. Therefore, nitric acid has been added to the model atmospheres as a separate atmospheric absorber.

The concentration of atmospheric nitric acid varies with altitude and also appears to depend on latitude and season. Figure 6 shows the volume mixing ratio

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Because of the large number of references cited above, they will not be listed here. See References, page 141.

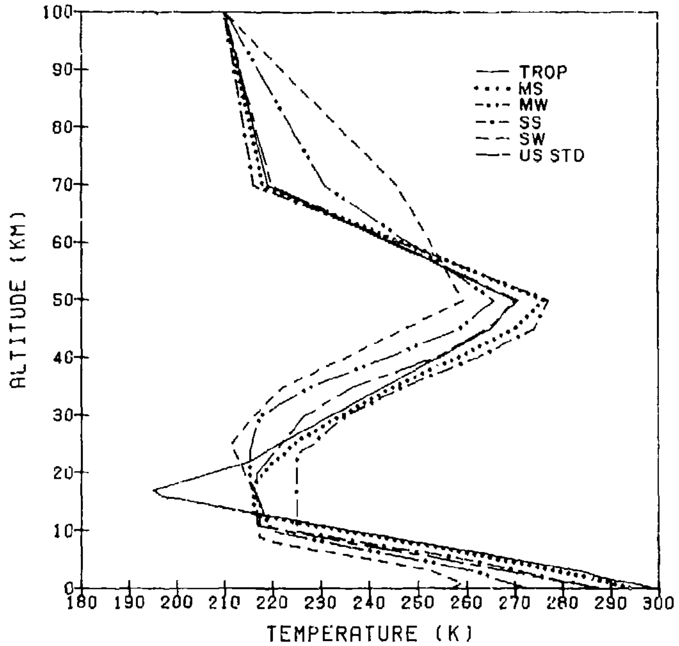

Figure 1. Temperature vs Altitude for the Six Model Atmospheres

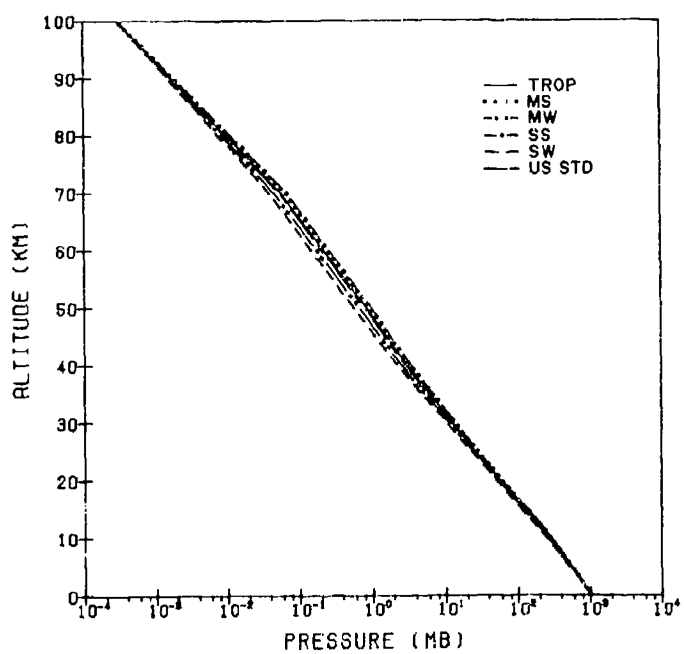

Figure 2. Pressure vs Altitude for the Six Model Atmospheres

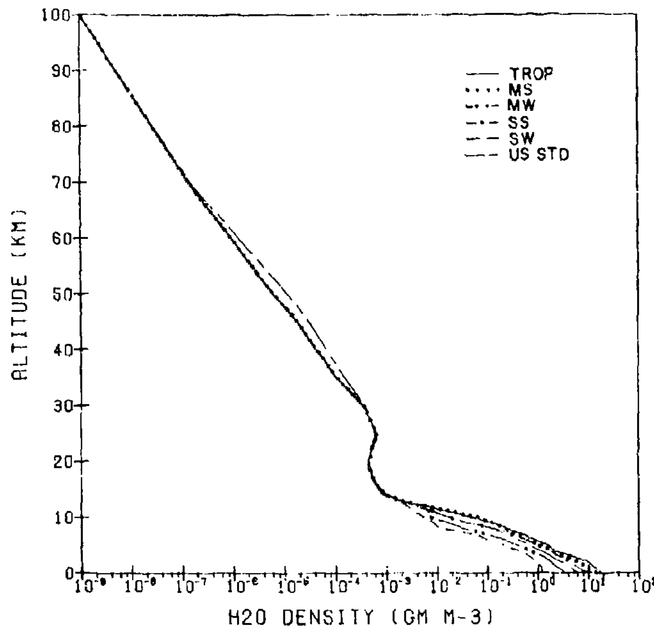

Figure 3a. Water Vapor Density Profiles vs Altitude for the Six Model Atmospheres

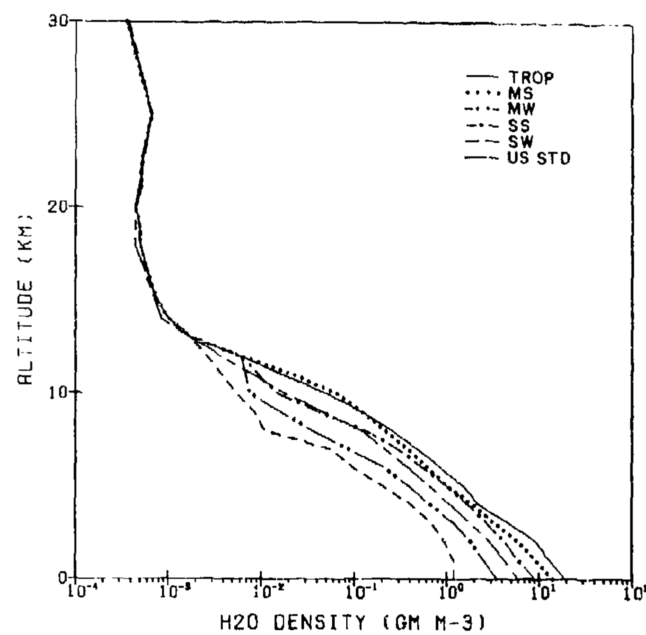

Figure 3b. Water Vapor Density Profiles vs Altitude for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

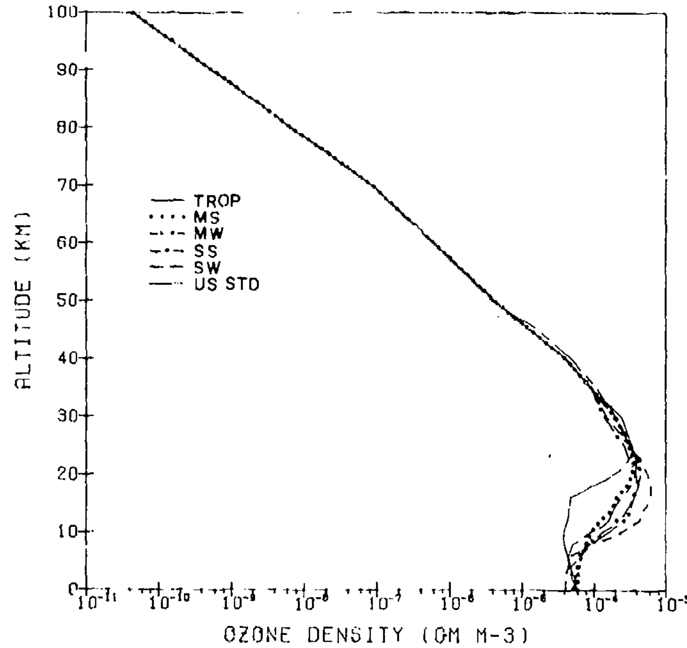

Figure 4a. Ozone Density Profiles vs Altitude for the Six Model Atmospheres

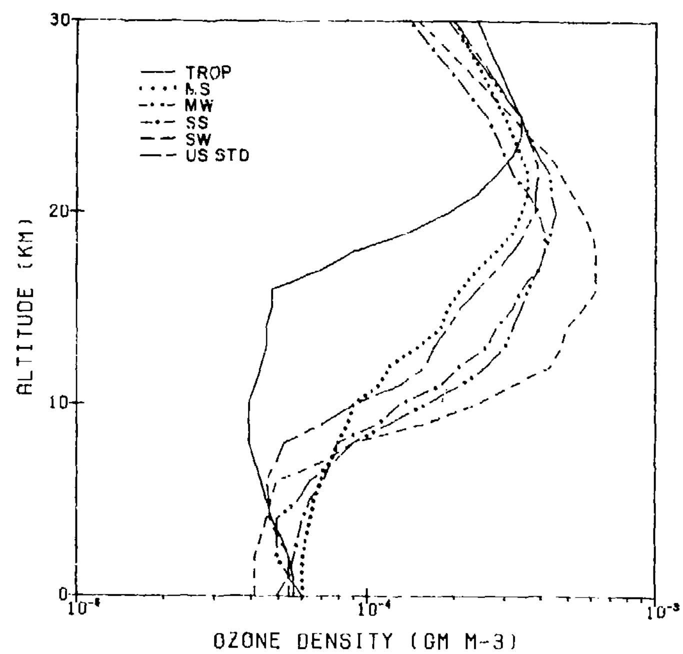

Figure 4b. Ozone Density Profiles vs Altitude for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

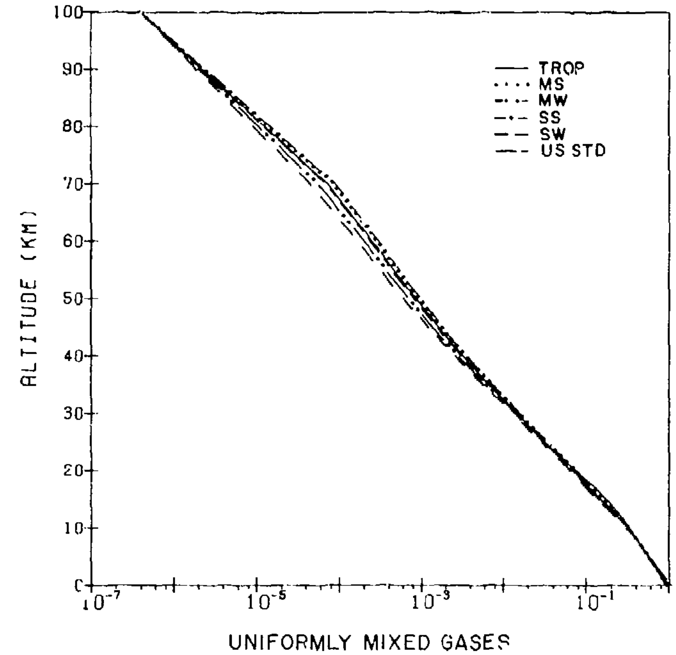

Figure 5a. Profile of $(P/P_0)(T_0/T)$, the Relative Air Density, vs Altitude for the Six Model Atmospheres. The density of the uniformly mixed gases is proportional to this quantity. $P_0 = 1013$ mb and $T_0 = 273$ K

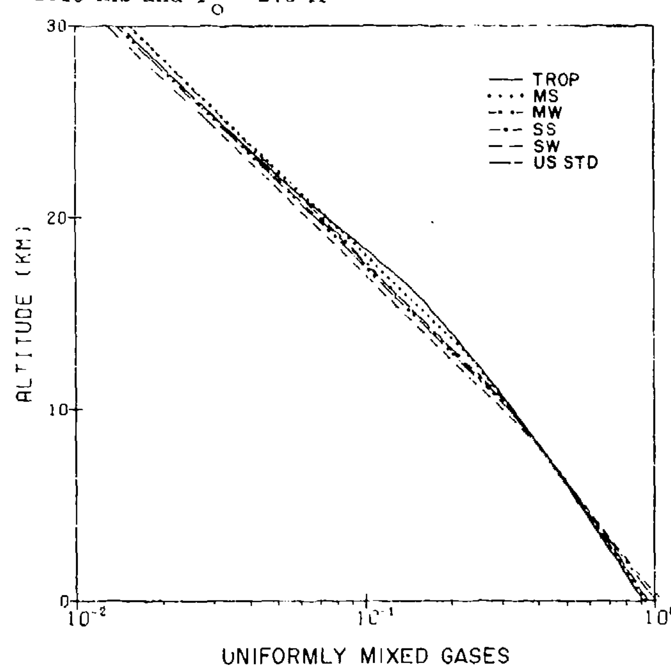

Figure 5b. Profile of $(P/P_0)(T_0/T)$, the Relative Air Density, vs Altitude for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

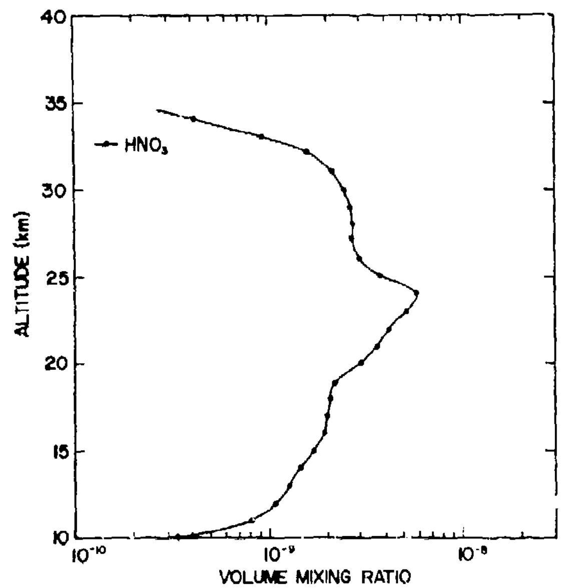

Figure 6. Volume Mixing Ratio Profile for Nitric Acid vs Altitude, from the Measurements of Evans, Kerr, and Wardle[10]. This single profile is used with all of the six model atmospheres

profile of atmospheric nitric acid as a function of altitude from the measurements of Evans, Kerr, and Wardle.[10] For the purpose of this report, we have chosen this profile to represent a mean nitric acid profile for the six model atmospheres in the LOWTRAN program. This profile appears in a data statement in the program. If a more definitive nitric acid profile for a given latitude and season is available, the user can change the nitric acid concentration by simply replacing the data statement given in the program.

In addition to the model atmospheres provided in this report, the user has the option of inserting his own model atmosphere (specifically designed for direct insertion of radiosonde data), or of building another model by combining various parts of the six standard models.

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10. Evans, W.F., Kerr, J.B., and Wardle, D.I. (1975) The AES Stratospheric Balloon Measurements Project: Preliminary Results, Atmospheric Environment Service, Downsview, Ontario, Canada, Report No. APRB 30 X 4.

3. AEROSOL MODELS

3.1 Introduction

The aerosol models built into LOWTRAN 5 have been completely revised from the earlier versions of the LOWTRAN code. Previous versions of LOWTRAN used the same model for aerosol composition and size distribution at all altitudes, simply changing the concentrations of the aerosols with height which means that the wavelength dependence of the aerosol extinction was independent of altitude.

The variation of the aerosol optical properties with altitude is now modeled by dividing the atmosphere into four height regions each having a different type of aerosol. These regions are the boundary or mixing layer (0 to 2 km), the upper troposphere (2 to 10 km), the lower stratosphere (10 to 30 km), and the upper atmosphere (30 to 100 km).

The earlier versions of LOWTRAN neglected changes in aerosol properties caused by variations in relative humidity. These aerosol models were representative of moderate relative humidities (around 80 percent). The models for the troposphere (rural, urban, maritime and tropospheric) which were previously used in LOWTRAN 3B and 4 have been updated according to more recent measurements and also are now given as a function of the relative humidity. In addition, two different fog models have been introduced into the program.

Only a brief description of the new aerosol models and their experimental and theoretical bases will be presented in this report since they are described elsewhere in detail.[11, 12]

3.2 Vertical Distribution in the Lower Atmosphere

The range of conditions in the boundary layer (up to 2 km) is represented by three different aerosol models (rural, urban, or maritime) for each of several

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11. Shettle, E. P., and Fenn, R. W. (1976) Models of the Atmospheric Aerosols and their Optical Properties, in AGARD Conference Proceedings No. 183 Optical Propagation in the Atmosphere. Presented at the Electromagnetic Wave Propagation Panel Symposium, Lyngby, Denmark, 27-31 October 1975, AGARD-CP-183, available from U.S. National Technical Information Service (No. AD-A028-615).

12. Shettle, E. P., and Fenn, R. W. (1979) Models of the Aerosols of the Lower Atmosphere and the Effects of Humidity Variations on their Optical Properties, AFGL-TR-79-0214, 17 September.

meteorological ranges* between 2 and 50 km, and as a function of humidity. In the boundary layer the shape of the aerosol size distribution and the composition of the three surface models are assumed to be invariant with altitude. Therefore only the total particle number is being varied. Although the total number density of air molecules decreases approximately exponentially with altitude, there is considerable experimental data which show that the aerosol concentration very often has a rather different vertical profile. One finds that, especially under moderate to low visibility conditions, the aerosols are concentrated in a uniformly mixed layer from the surface up to about 1- to 2-km altitude and that this haze layer has a rather sharp top, which appears to be associated with the height of the minimum temperature lapse rate.[13]

The vertical distribution for clear to very clear conditions, or meteorological ranges from 23 and 50 km, is taken to be exponential, similar to the profiles used in previous versions of LOWTRAN. However, for the hazy conditions (10-, 5-, and 2-km meteorological ranges) the aerosol extinction is taken to be independent of height up to 1 km with a pronounced decrease above that height.

Above the boundary layer in the troposphere the distribution and nature of the atmospheric aerosols becomes less sensitive to geography and weather variations. Instead, the seasonal variations are considered to be the dominating factor. The aerosol concentration measurements of Blifford and Ringer[16] and Hoffman et al[17]

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*The terms "meteorological range" and "visibility" are not always used correctly in the literature. Correctly,[14, 15] visibility is the greatest distance at which it is just possible to see and identify with the unaided eye: (a) in the daytime, a dark object against the horizon sky; and (b) at night, a known moderately intense light source. Meteorological range is defined quantitatively, eliminating the subjective nature of the observer and the distinction between day and night. Meteorological range V is defined by the Koschmieder formula

$$V = \frac{1}{\beta} \ln \frac{1}{\epsilon} = \frac{3.912}{\beta}$$

where β is the extinction coefficient, and ϵ is the threshold contrast, set equal to 0.02. As used in the LOWTRAN computer code, the inputs are in terms of meteorological range, with β, the extinction coefficient, evaluated at 0.55 μm. If only an observer visibility V_{obs} is available, the meteorological range can be estimated as $V \approx (1.3 \pm 0.3) \cdot V_{obs}$.

13. Johnson, R.W., Hering, W.S., Gordon, J.I., and Fitch, B.W. (1979) Preliminary Analysis and Modelling Based Upon Project OPAQUE Profile and Surface Data, AFGL-TR-79-0285, November.

14. Huschke, R.E. (editor) (1959) Glossary of Meteorology, American Meteorlogical Society, Boston, MA, 638 pp.

15. Middleton, W.E.K. (1952) Vision Through the Atmosphere, Univ. of Toronto Press, 250 pp.

16. Blifford, I.H., and Ringer, L.D. (1969) The size and number distribution of aerosols in the continental troposphere, J. Atmos. Sci. 26:716-726.

17. Hofmann, R.J., Rosen, J.M., Pepin, T.J., and Pinnick, R.G. (1975) Stratospheric aerosol measurements I: Time variations at northern latitudes, J. Atmos. Sci. 32:1446-1456.

indicate that there is an increase in the particulate concentration in the upper troposphere during the spring and summer months. This is also supported by an analysis of searchlight data by Elterman et al.[18]

The vertical distribution of the aerosol concentrations for the different models is shown in Figure 7. Between 2 and 30 km, where a distinction on a seasonal basis is made, the spring-summer conditions are indicated with a solid line and fall-winter conditions are indicated by a dashed line.

3.3 Effects of Humidity Variations on Aerosol Properties

The basic effect of changes in the relative humidity on the aerosols, is that as the relative humidity increases, the water vapor condenses out of the atmosphere onto the existing atmospheric particulates. This condensed water increases the size of the aerosols, and changes their composition and their effective refractive index. The resulting effect of the aerosols on the absorption and scattering of light will correspondingly be modified. There have been a number of studies of the change of aerosol properties as a function of relative humidity.[12, 19] The most comprehensive of these, especially in terms of the resulting effects on the aerosol properties is the work of Hänel.[19, 20]

The growth of the particulates as a function of relative humidity is based on the results tabulated by Hänel[19] for different types of aerosols. Once the wet aerosol particle size is determined, the complex refractive index is calculated as the volume-weighted average of the refractive indices of the dry aerosol substance and water.[21]

3.4 Rural Aerosols

The "rural model" is intended to represent the aerosol conditions one finds in continental areas which are not directly influenced by urban and/or industrial aerosol sources. This continental, rural aerosol background is partly the product of reactions between various gases in the atmosphere and partly due to dust particles picked up from the surface. The particle concentration is largely dependent

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18. Elterman, L., Wexler, R., and Chang, D.T. (1969) Features of tropospheric and stratospheric dust, Appl. Opt. 8:893-903.

19. Hänel, Gottfried (1976) The properties of atmospheric aerosol particles as functions of the relative humidity at thermodynamic equilibrium with the surrounding moist air, in Advances in Geophysics, Vol 19:73-188, Edited by H. E. Landsberg, J. Van Mieghem, Academic Press, New York.

20. Hänel, Gottfried (1972) Computation of the extinction of visible radiation by atmospheric aerosol particles as a function of the relative humidity, based upon measured properties, Aerosol Sci. 3:377-386.

21. Hale, George M., and Querry, Marvin R. (1973) Optical constants of water in the 200-nm to 200-μm wavelength region, Appl. Opt. 12:555-563.

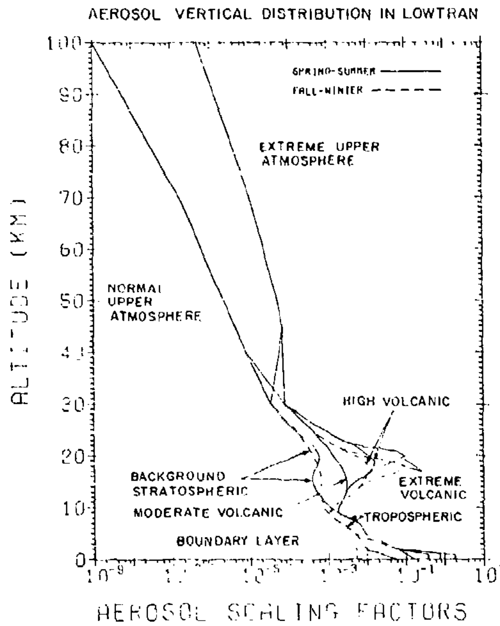

Figure 7a. Vertical Profiles of Aerosol Scaling Factors vs Altitude

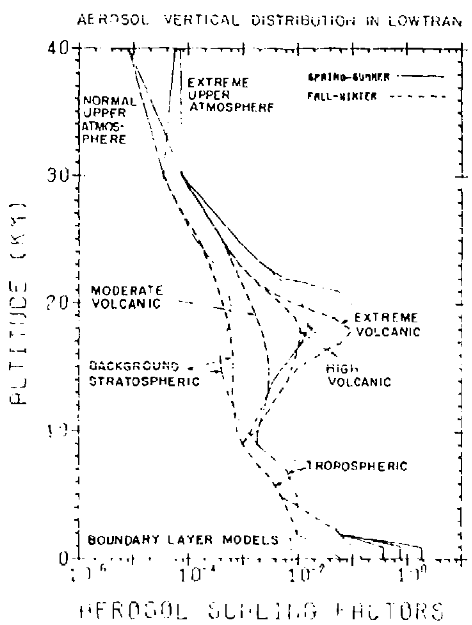

Figure 7b. Vertical Profiles of Aerosol Scaling Factors vs Altitude with the Region from 0 to 40 km Expanded

on the history of the air mass carrying the aerosol particles. In stagnating air masses, for example, under winter-type temperature inversions, the concentrations may increase to values causing the surface layer visibilities to drop to a few kilometers.

The rural aerosols are assumed to be composed of a mixture of 70 percent of water-soluble substance (ammonium and calcium sulfate and also organic compounds) and 30 percent dust-like aerosols. The refractive index for these components is based on the measurements of Volz.[22, 23]

The rural aerosol size distribution is parameterized as the sum of two log-normal size distributions, to represent the multimodal nature of the atmospheric aerosols that has been discussed in various studies. These parameters for rural model size distribution fall within what Whitby and Cantrell[24] give as a typical range of values for the accumulation (small) and coarse (large) particle modes.

To allow for the dependence of the humidity effects on the size of the dry aerosol, the growth of the aerosol was computed separately for the accumulation and coarse particle components. In computing the aerosol growth, changes in the width of the size distribution was assumed negligible so only the mode radius was modified by humidity changes. The effective refractive indices for the two size components are then computed as function of relative humidity.

Using Mie theory for scattering by spherical particles, the extinction and absorption coefficients for each of several different relative humidities were calculated. Figure 8 shows the resulting values for the different relative humidities which are stored in the LOWTRAN code. The values have been normalized to an extinction coefficient of 1.0 at a wavelength of 0.55 μ, which is the way values are used in the program.

3.5 Urban Aerosol Model

In urban areas the rural aerosol background gets modified by the addition of aerosols from combustion products and industrial sources. The urban aerosol model therefore was taken to be a mixture of the rural aerosol with carbonaceous aerosols. The sootlike aerosols are assumed to have the same size distribution as both components of the rural model. The proportions of the sootlike aerosols and the rural type of aerosol mixture are assumed to be 20 percent and 80 percent

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22. Volz, Frederic E. (1972) Infrared absorption by atmospheric aerosol substances, J. Geophys. Res. 77:1017-1031.

23. Volz, Frederic E. (1973) Infrared optical constants of ammonium sulfate, Sahara dust, volcanic pumice, and flyash, Appl. Opt. 12:564-568.

24. Whitby, K.T., and Cantrell, B. (1975) Atmospheric aerosols – characteristics and measurement, International Conf. on Environmental Sensing and Assessment, Vol. 2, Las Vegas, Nev., 14-19 September.

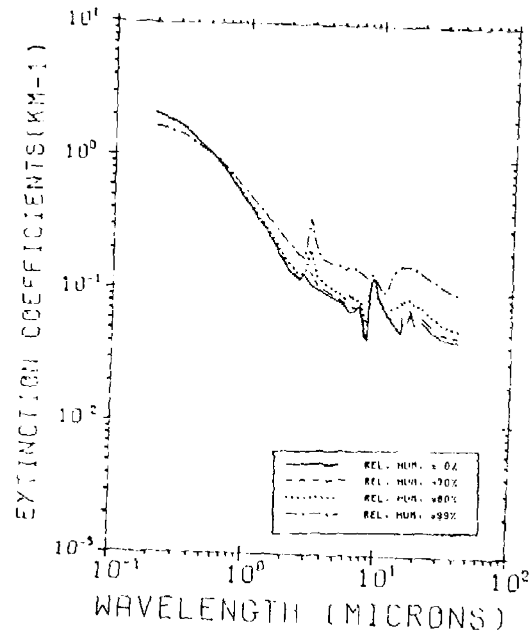

Figure 8a. Extinction Coefficients for the Rural Aerosol Model (Normalized to 1.0 at 0.55 μ)

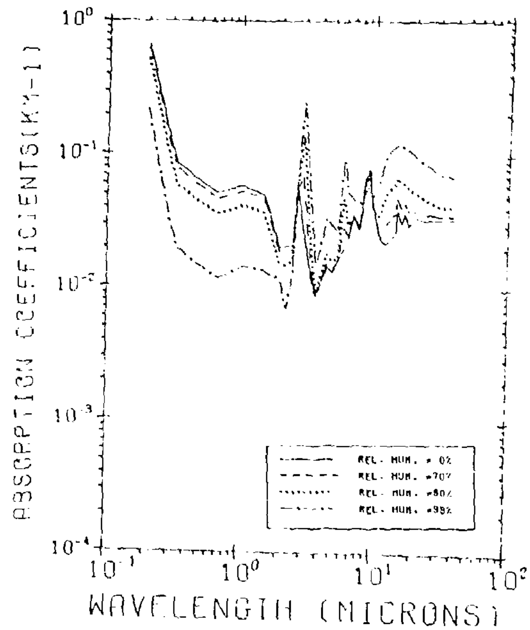

Figure 8b. Absorption Coefficients for the Rural Aerosol Model Corresponding to Figure 8a

respectively. The refractive index of the sootlike aerosols was based on the soot data in Twitty and Weinman's[25] survey of the refractive index of carbonaceous materials.

Figure 9 shows the extinction and absorption coefficients for the urban models vs wavelength. As with the rural model the values are normalized so the extinction coefficient is 1.0, at a wavelength of 0.55 μ.

3.6 Maritime Aerosol Model

The composition and distribution of aerosols of oceanic origin is significantly different from continental aerosol types. These aerosols are largely sea-salt particles which are produced by the evaporation of sea-spray droplets and then have again grown due to accretion of water under high relative humidity conditions. Together with a background aerosol of more or less pronounced continental character they form a fairly uniform maritime aerosol which is representative of the boundary layer in the lower 2 to 3 km of the atmosphere over the oceans, but which also will occur over the continents in a maritime air mass. This maritime model should be distinguished from the direct sea-spray aerosol which exists in the lower 10 to 20 meters above the ocean surface and which is strongly dependent on wind speed.

The maritime aerosol model, therefore, has been composed of two components: one which developed from sea spray; and a continental component which is assumed identical to the rural aerosol with the exception that the very large particles were eliminated, since they will eventually be lost due to fallout as the air masses move across the oceans. This model is similar to the one suggested by Junge[26, 27] and is supported by a large body of experimental data.[12]

The refractive index is the same as that for a solution of sea salt in water, using a volume-weighted average of the refractive indices of water and sea salt. The refractive index of the sea salt is primarily taken from the measurements of Volz.[28] The normalized extinction and absorption coefficients vs wavelength for the maritime aerosols are shown in Figure 10 for several relative humidities.

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25. Twitty, J.T., and Weinman, J.A. (1971) Radiative properties of carbonaceous aerosols, J. Appl. Meteor. 10:725-731.

26. Junge, Christian E. (1963) Air Chemistry and Radioactivity, 382 pp., Academic Press, New York.

27. Junge, C.E. (1972) Our knowledge of the physico-chemistry of aerosols in the undisturbed marine environment, J. Geophys. Res. 77:5183-5200.

28. Volz, Frederic E. (1972) Infrared refractive index of atmospheric aerosol substance, Appl. Opt. 11:755-759.

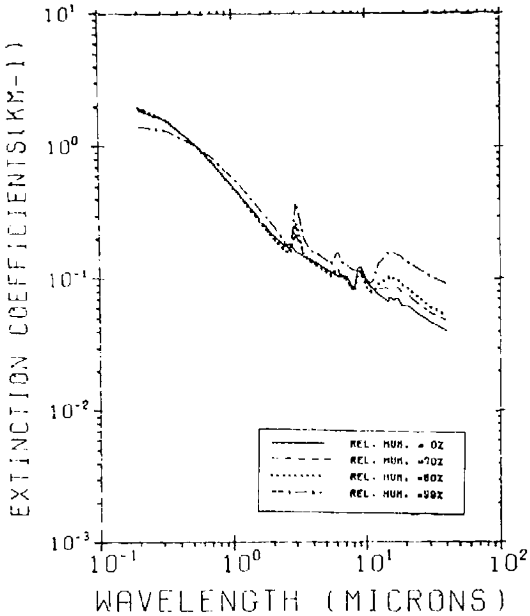

Figure 9a. Extinction Coefficients for the Urban Aerosol Model (Normalized to 1.0 at 0.55 μ)

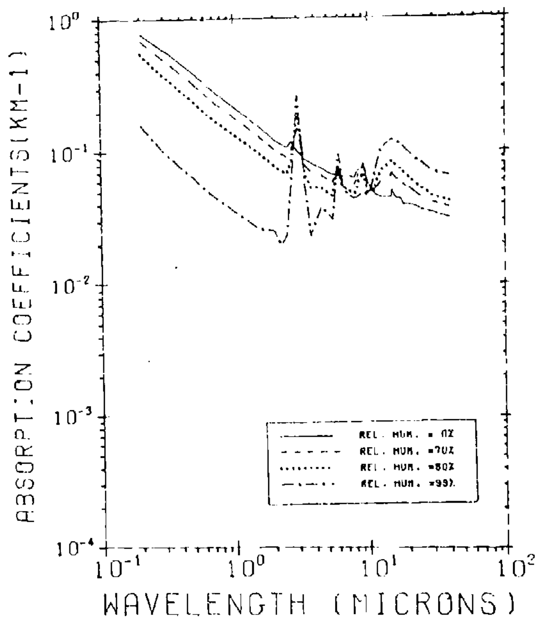

Figure 9b. Absorption Coefficients for the Urban Aerosol Model Corresponding to Figure 9a

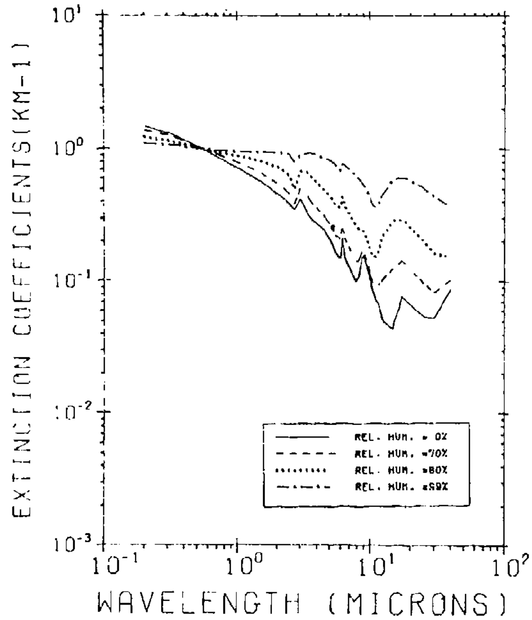

Figure 10a. Extinction Coefficients for the Maritime Aerosol Model (Normalized to 1.0 at 0.55 μ)

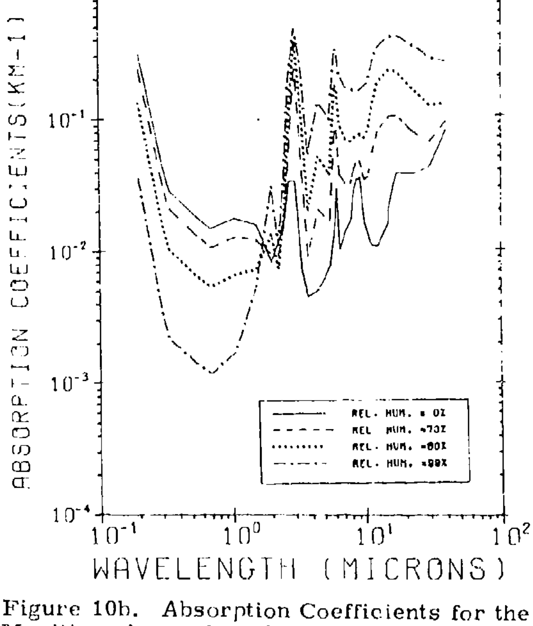

Figure 10b. Absorption Coefficients for the Maritime Aerosol Model Corresponding to Figure 10a

3.7 Tropospheric Aerosol Model

Above the boundary layer in the troposphere, the aerosol properties become more uniform and can be described by a general tropospheric aerosol model. The tropospheric model represents an extremely clear condition and can be represented by the rural model without the large particle component. Larger aerosol particles will be depleted due to settling with time. This is consistent with the changes in aerosol size distribution with altitude suggested by Whitby and Cantrell.[24]

There is some indication from experimental data, that the tropospheric aerosol concentrations are somewhat higher during the spring-summer season than during the fall-winter period.[16, 17] Different vertical distributions are given to represent these seasonal changes (see Section 3.2).

The dependence of the particle size on relative humidity is the same as for the small particle component of the rural model. The resulting normalized extinction and absorption coefficients are shown in Figure 11 for the different relative humidities.

3.8 Fog Models

When the air becomes nearly saturated with water vapor (relative humidity close to 100 percent), fog can form (assuming sufficient condensation nuclei are present). Saturation of the air can occur as the result of two different processes; the mixing of air masses with different temperatures and/or humidities (advection fogs), or by cooling of the air to the point where its temperature approaches the dew-point temperature (radiation fogs).[29]

To represent the range of the different types of fog, we use two of the fog models presented by Silverman and Sprague,[30] following the work of Dyachenko.[31] These were chosen to represent the range of measured size distributions, and correspond to what Silverman and Sprague[30] identified as typical of radiation fogs and advection fogs, although they also describe developing and mature fogs, respectively. The normalized extinction and absorption coefficients for the two fog models are shown in Figure 12 as a function of wavelength.

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29. Byers, H.R. (1959) General Meteorology, 540 pp., McGraw Hill, New York.

30. Silverman, B.A., and Sprague, E.D. (1970) Airborne measurement of in-cloud visibility, 271-276, Second National Conference on Weather Modification, Santa Barbara, CA, 6-9 April 1970, American Meteorological Society.

31. Dyanchenko, P.V. (1962) Experimental Application of the Method of Mathematical Statistics to Microstructural Fog and Cloud Research, Trans. A.I. Voyekova, Main Geophys. Obser.

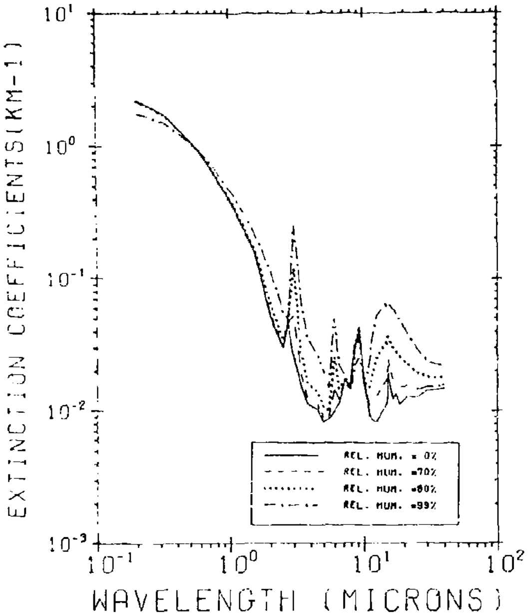

Figure 11a. Extinction Coefficients for the Tropospheric Aerosol Model (Normalized to 1.0 at 0.55 μ)

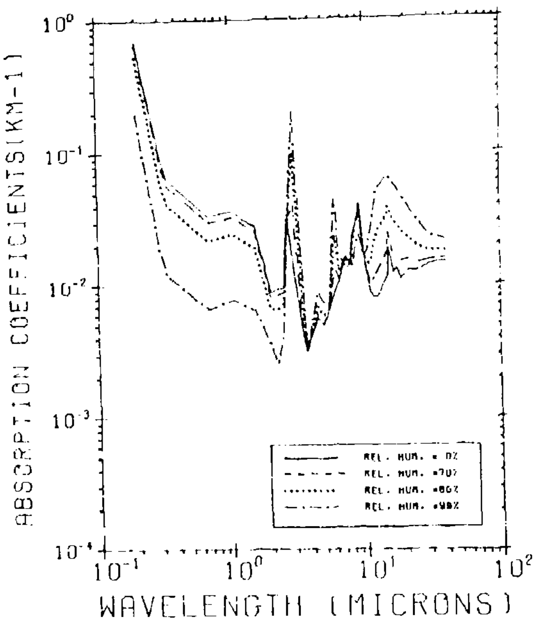

Figure 11b. Absorption Coefficients for the Tropospheric Aerosol Model Corresponding to Figure 11a

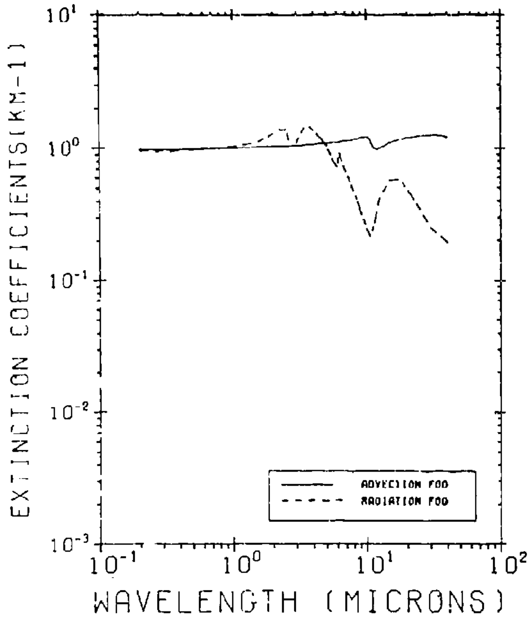

Figure 12a. Extinction Coefficients for the Fog Models (Normalized to 1.0 at 0.55 μ)

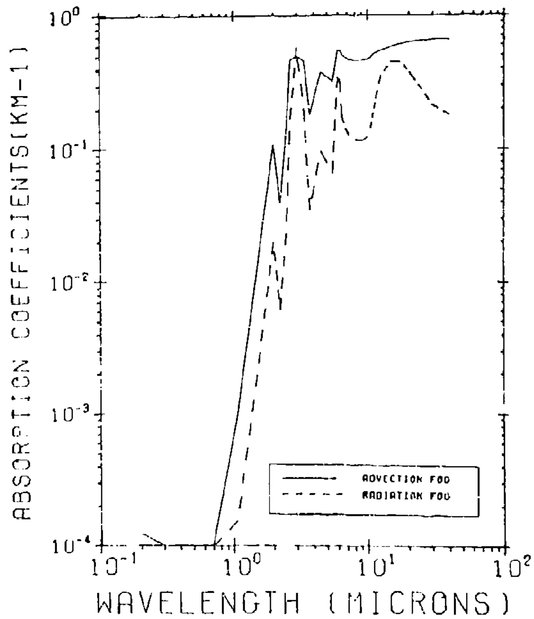

Figure 12b. Absorption Coefficients for the Fog Models Corresponding to Figure 12a

3.9 Aerosol Vertical Distribution in the Stratosphere and Mesosphere

Measurement programs carried out over many years show that in the 10- to 30-km region there exists a background aerosol in the stratosphere which has a rather uniform global distribution. The background aerosol is considered to be mostly composed of sulfate particles formed by photochemical reactions.

These background levels are occasionally increased by factors of 100 or more due to the injection of dust from massive volcanic eruptions. Once such particles have been injected into the stratosphere they are spread out over large portions of the globe by the stratospheric circulation and diffusion processes, and it requires months or even years for them to become slowly removed from the stratosphere.[32, 33, 34]

There occurs also a seasonal and geographic variation of the stratospheric aerosol layer which is related to the height of the tropopause; a peak in the aerosol mixing ratio (that is, ratio of aerosol to air molecules) occurs several kilometers above the tropopause.[17, 35]

The range of possible vertical distributions is represented by four different profiles (background stratospheric, moderate, high and extreme volcanic). Each of these distributions is then modified according to the season. The different scaling factors for these vertical profiles are shown in Figure 7.

The vertical distribution in the upper atmosphere above 30 to 40 km is very uncertain because of the difficulty of obtaining reliable data. In situ measurements are limited to those obtained by rocket flights, and these altitudes are beyond the normal operational range of most lidar and searchlight systems which provide most of the remotely sensed data up to 30 or 40 km.

The most likely profile for this region is the one labelled as "Normal Upper Atmosphere" in Figure 7; it corresponds to a constant turbidity ratio of ≈ 0.2 above 40 km. This agrees with the aerosol extinction profile obtained by Cunnold et al[36] by inverting measurements of the horizon radiance from an X-15 aircraft.

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32. Reiter, E.R. (1971) Atmospheric Transport Processes Part 2: Chemical Tracers, U.S. Atomic Energy Commission, Oak Ridge, TN (TID-25314) 382 pp.

33. Volz, F.E. (1975) Distribution of turbidity after the 1912 Katmei Eruption in Alaska, J. Geophys. Res. 80:2643-2648.

34. Volz, F.E. (1975) Burden of volcanic dust and nuclear debris after injection into the stratosphere at 40°-58°N., J. Geophys. Res. 80:2649-2652.

35. Rosen, J.M., Hofmann, D.J., and Laby, J. (1975) Stratospheric measurements II: the worldwide distribution, J. Atmos. Sci. 32:1457-1462.

36. Cunnold, D.M., Gray, C.R., and Merritt, D.C. (1973) Stratospheric aerosol layer detection, J. Geophys. Res. 78:920-931.

Measurements of the solar extinction through the atmospheric limb from the Apollo-Soyuz mission[37] tend to support this model.

Ivlev's[38, 39] model for the upper atmosphere is shown as the curve labelled "Extreme Upper Atmosphere" in Figure 7. It is largely based on twilight observations[40] which neglected multiple-scattering effects. As a consequence, the model has to assume very high particulate concentrations in the upper atmosphere in order to be consistent with observations.

Nevertheless, extinction coefficients for the extreme upper-atmospheric model are consistent with the extreme values that have been observed in layers of a few kilometers thickness by lidar,[41, 42] inferred from rocket observations of skylight,[43, 44] and studies of noctilucent clouds.[45]

3.10 Stratospheric Aerosol Models

3.10.1 COMPOSITION OF BACKGROUND STRATOSPHERIC AEROSOLS

The background stratospheric aerosols are taken to be a 75 percent solution of sulfuric acid in water following the work of Rosen[46] and Toon and Pollack.[47] The complex refractive index as a function of wavelength is based on the measurements of Remsberg[48, 49] and Palmer and Williams.[50]

The size distribution is chosen to be consistent with the concentrations of the particles with diameters greater than 0.3 μ and those greater than 0.5 μ measured by Hofman et al[17, 35] and the concentration of condensation nuclei observed by Rosen et al[51] and Käselau.[52] The normalized extinction and absorption coefficients are shown in Figure 13.

3.10.2 VOLCANIC AEROSOL MODELS

There are two volcanic size distribution models: a "fresh volcanic model" which represents the size distribution of aerosols shortly after a volcanic eruption; and an "aged volcanic model" representing the aerosol about a year after an eruption. Both size distributions were chosen mainly on the basis of Mossop's[53] measurements following the eruption of Mt. Agung.

The refractive index for these models is based on the measurements of Volz.[23] The resulting normalized extinction and absorption coefficients for these two models are shown in Figure 13.

Because of the large number of references cited above, they will not be listed here. See References, page 141.

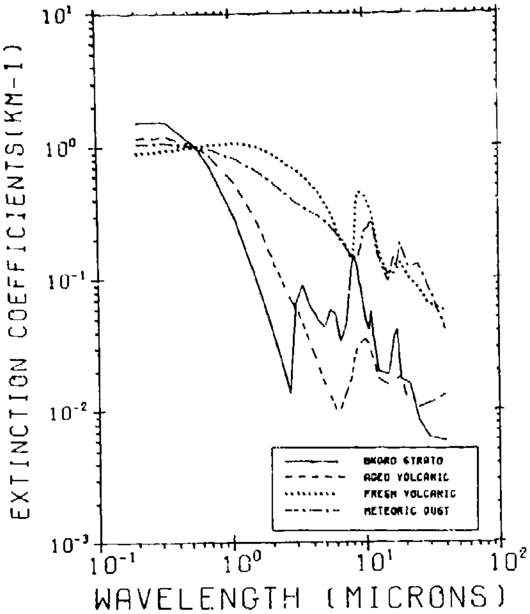

Figure 13a. Extinction Coefficients for the Upper Atmospheric Aerosol Models (Normalized to 1.0 at 0.55 μ)

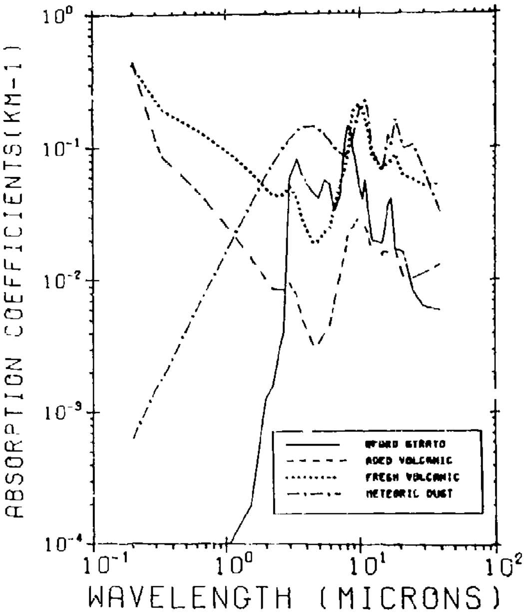

Figure 13b. Absorption Coefficients for the Upper Atmospheric Aerosol Models Corresponding to Figure 13a

3.11 Upper Atmosphere Aerosol Model

The major component of the normal upper-atmospheric aerosols is considered to be meteoric dust, which is consistent with the conclusions reached by Newkirk and Eddy[54] and later Rosen[55] in his review article. Meteoric or cometary dust also form some of the layers occasionally observed in the upper atmosphere. Poultney[42, 56] has related the lidar observations of layers in the upper atmosphere either to cometary sources of micrometeoroid showers or noctilucent cloud observations. Divari et al[57] have related observations of increased brightness of the twilight sky to the Orinid meteor shower.

The refractive index of meteoric dust is based on the work of Shettle and Volz[58] who determined the complex refractive index for a mixture of chondrite dust which represents the major type of meteorite falling on the earth.[59]

The size distribution is similar in shape to the one developed by Farlow and Ferry[60] by applying Kornblum's[61, 62] theoretical analysis (of the micrometeoroid interaction with the atmosphere and their resulting concentration in the mesosphere) to the NASA[63] model of the meteoroid influx to the atmosphere. There are two important differences between the present size distribution model and Farlow and Ferry's.[60] First, the present model has proportionately more smaller particles,

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54. Newkirk, G. Jr., and Eddy, J.A. (1964) Light Scattering by Particles in the Upper Atmosphere, J. Atmos. Sci. 21:35-60.
55. Rosen, J.M. (1969) Stratospheric dust and its relationship to the meteoric influx, Space Sci. Rev. 9:58-89.
56. Poultney, S.K. (1974) Times, locations and significance of cometary micrometeoroid influxes in the earth's atmosphere, Space Res. 14:707-708.
57. Divari, N.B., Zaginalio, Yu. I., and Koval'chuk, L.V. (1973) Meteoric dust in the upper atmosphere, Solar System Res. 7:191-195. (Translated from Astronomicheskii Vestnik 7:223-230).
58. Shettle, E.P., and Volz, F.E. (1976) Optical constants for a meteoric dust aerosol model, in Atmospheric Aerosols: Their Optical Properties and Effects, a Topical Meeting on Atmospheric Aerosols sponsored by Optical Society of America and NASA Langley Research Center, Williamsburg, Virginia, 13-15 December 1976, NASA CP-2004.
59. Gaffey, M.J. (1974) A Systematic Study of the Spectral Reflectivity Characteristics of the Meteorite Classes with Applications to the Interpretation of Asteroid Spectra for Mineralogical and Petrological Information, Ph.D Thesis, M.I.T.
60. Farlow, N.H., and Ferry, G.V. (1972) Cosmic dust in the mesophere, Space Res. 12:369-380.
61. Kornblum, J.J. (1969) Micrometeoroid interaction with the atmosphere, J. Geophys. Res. 74:1893-1907.
62. Kornblum, J.J. (1969) Concentration and collection of meteoric dust in the atmosphere, J. Geophys. Res. 74:1908-1919.
63. National Aeronautics and Space Administration (1969) Meteoroid Environment Model, 1969 (Near Earth to Lunar Surface), NASA SP-8013 (March 1969).

and second, the number densities for all size ranges are several orders of magnitude larger than in Farlow and Ferry's[60] model. These differences are consistent with rocket observations in the upper atmosphere.[60, 64, 65]

The normalized extinction and absorption coefficients for this meteoric dust model for the aerosols of the upper atmosphere are shown in Figure 13 as a function of wavelength.

3.12 Use of the Aerosol Models

The aerosol models defined in this report are representative of various general types of environments. Yet, the simple question: "Which model should be used for what location and weather situation?" is difficult to answer precisely. Some discussion on this point is necessary to give the user some guidance in choosing the appropriate model for a given condition.

3.12.1 BOUNDARY LAYER MODELS

For the boundary layer of the atmosphere up to 1 to 2 km above the surface, the composition of the aerosol particles is primarily controlled by sources (natural and man-made) at the earth's surface. The aerosol content of the atmosphere at a given location, will therefore depend on the trajectory of the local air mass during the preceding several days, and the meteorological history of the air mass. The amount of mixing in the atmosphere is controlled by the temperature profile and the winds. Precipitation will tend to wash the aerosol out of the atmosphere, although it should be noted that "frontal showers" often mark the boundary between two different air masses with generally different histories and correspondingly different aerosol contents.

The "rural" and the "urban" model are intended to distinguish between aerosol types of natural and man-made origin over a land area. Clearly, the man-made aerosol will be predominantly found in urban-industrial areas. How ver, it is quite likely that after the passage of a cold front, clear polar air also covers an urban area and that therefore the rural aerosol model, which is free of the component of industrial-carbonaceous aerosols, is more applicable. After a few days, as the clean air mass begins to accumulate local pollution however, the urban model will once again become more representative.

Conversely, very often the pollution plume from major urban-industrial areas may, under stagnant weather conditions, diffuse over portions of a continent (for example, Central Europe, Northeastern United States), including its rural sections.

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64. Soberman, R.K., and Hemenway, C.L. (1965) Meteoric dust in the upper atmosphere, J. Geophys. Res. 70:4943-4949.

65. Lindblad, B.A., Arinder, G., and Wiesel, T. (1973) Continued rocket observations of micrometeorites, Space Res. 13:1113-1120.

There is also a distinct difference between the composition of aerosols over the ocean and those over land areas due to the different surface-based sources. Aerosols in maritime environments have a very pronounced component of sea-salt particles from the sea water. Sea-salt particles are formed from sea spray from breaking waves. The larger particles fall out, but the smaller particles are transported up with the atmospheric mixing in the boundary layer. In coastal regions the relative proportions of particles of continental and oceanic origins will vary, depending on the strength and direction of the prevailing winds at time of observation.

While changes in visibility are often associated with changes in the relative humidity, (as the relative humidity approaches 100 percent the visibility tends to decrease), it is not possible to define a unique functional relationship between the visibility and relative humidity in the natural atmosphere. The reason for this is that any change in atmospheric moisture content is generally also associated with a change in the aerosol population itself due to change of the air mass. Only if the aerosol is contained in a closed system, where only the humidity changes, can such a unique relationship be developed. The measurements presented by Filippov and Mirumyants[66] clearly illustrate the difficulties in defining a simple unique expression relating visibility and relative humidity.

3.12.2 TROPOSPHERIC AEROSOL MODEL

The tropospheric aerosol model has been developed primarily for application in the troposphere, above the boundary layer, where the aerosols are not as sensitive to local surface sources. However, the tropospheric model should be used near ground level for particularly clear and calm conditions (in pollution-free areas with visibilities greater than 30 to 40 km), where there has been little turbulent mixing for a period of 1 to 2 days, permitting the larger particles to have settled out of the atmosphere without being replaced by dust blown into the air from the surface. (The sedimentation rate of a 10-μm radius aerosol particle in the lower troposphere is approximately 1 km per day.[67])

3.12.3 FOG MODELS

The fog models described in Section 3.9 were presented in terms of the atmospheric conditions leading to the development of the fog, so this provides a good basis for deciding which fog model to use. In more general terms, the visibilities will be less than 200 m for thick fogs and the extinction will be virtually

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66. Filippov, V.L., and Mirumyants, S.O. (1972) Aerosol extinction of visible and infrared radiation as a function of air humidity, Izv. Atmos. Oceanic Phys. 8:571-574.

67. Kasten, F. (1968) Falling speed of aerosol particles, J. Appl. Meteor. 7:944-947.

independent of wavelength. For these conditions the advection fog model should be used. For light to moderate fogs, the visibility will be 200 to 1000 m and there will be a noticeable difference between the extinction for visible wavelengths and in the 8- to 12-μm window. For such cases the radiation fog model should be used. For thin fog conditions where the visibility may be 1 to 2 km, the 99 percent relative humidity aerosol models may represent the wavelength dependence of the atmospheric extinction as well as any of the fog models.

3.12.4 STRATOSPHERIC AND UPPER ATMOSPHERE MODELS

The background stratospheric model is representative of present (1980)* stratospheric conditions. At irregular intervals (on the order of years) there are volcanic eruptions which inject significant amounts of aerosols into the stratosphere. For the first few months following such an eruption the fresh volcanic size distribution model would generally be the best one to use, and for the next year or so after that the aged volcanic size distribution model should be used.

The choice of which vertical distribution profile to use would depend on the severity of the volcanic eruption and how long ago it was. The moderate volcanic profile is representative of the stratospheric conditions throughout the Northern Hemisphere during the mid and late 1960's following the eruption of Mt. Agung. It is also typical of conditions during late 1974 and 1975 after the Volcan de Fuego eruption.

The high and extreme volcanic models are somewhat speculative as there have been no direct measurements of the vertical distribution of aerosol for such conditions. They are however consistent with the total optical thickness for aerosols inferred shortly after several major volcanic eruptions,[33, 34, 68] such as Katmai and Krakatoa, as well as the effects of Mt. Agung in the Southern Hemisphere.

3.12.5 SEASONAL AND LATITUDE DEPENDENCE OF AEROSOL VERTICAL DISTRIBUTION

In the mid-latitudes as the names suggest the spring-summer aerosol vertical profiles are intended to be used during the spring and summer seasons and the fall-winter profiles used during the fall and winter seasons. However, the seasonal changes in aerosol distribution are partially a reflection of the changes in

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*Note added in Proof. The eruption of Mt. St. Helens (May 1980) injected significant amounts of volcanic dust into the atmosphere. However, it appears most of it remained in the troposphere where it can be expected to settle out or be washed out within a few weeks. On the basis of the limited quantitative information available at this early date, a best guess would be to use the moderate volcanic profile to represent the amount added to the stratosphere.

68. Diermendjian, D. (1973) On volcanic and other turbidity anomalies, Advances in Geophys. 16:267-296.

Table 1. Typical Conditions for Aerosol Model Applications

1. Lower Atmospheric Models

1.1 Rural Model

1) Natural environment, midlatitude, overland.
2) Clean air in urban regions, following passage of a cold front.

1.2 Urban Model

1) Urban industrial aerosol.
2) Stagnant polluted air extending into rural regions.

1.3 Maritime Model

1) Mid-ocean (at least 300 km offshore) with moderate winds (above the first 10 to 20 meters).
2) Continental areas under strong prevailing wind from the ocean.

1.4 Tropospheric Model

1) Atmospheric region between top of boundary layer (approximately 2 km) and tropopause (8-18 km, depending on latitude and season).
2) Clean, calm air (meteorological range $\geq$ 40 km) in surface layer over land.

1.5 Fog Models

1.5.1 Advective Fog

1) Mixing of air masses of different moisture content and temperature, leading to saturation.
2) Lacking specific knowledge on the formation process, for mature fogs with meteorological range: $V \leq 200$ meters.

1.5.2 Radiation Fog

1) Radiational cooling of the air to the dew point at night.
2) Lacking specific knowledge on the formation process, for developing fogs or meteorological ranges: $200 \leq V \leq 1000$ meters.

1.5.3 99 Percent Relative Humidity Aerosol Models

1) Light fogs ($1 \leq V \leq 2$ km).

2. Stratospheric and Mesopheric Aerosol Models

2.1 Background Stratospheric Model

For time periods without any direct influence of volcanic dust contamination, for example, 1977 to present (1980). (See footnote pg. 39)

2.2 Moderate Volcanic Profile with Fresh Aged Particle Size Distribution

For optical thickness approximately 0.03, up to a few years after eruption, for example, Northern Hemisphere, 1964 to 1968.

2.3 High Volcanic Profile and Fresh or Aged Particle Size Distribution

For optical thickness approximately 0.1, up to a few months after eruption, for example, Southern Hemisphere, 1964-1965.

2.4 Extreme Volcanic Profile with Fresh Particle Size Distribution

For optical thickness approximately 0.3 or higher, up to a few weeks after a major eruption, for example, 1883 (Krakatoa) or 1912 (Katmai).

the tropopause height (especially for stratospheric aerosols). So in the tropical regions where the tropopause is generally higher, it is recommended that the spring-summer aerosol profile be used. Analogously is the subarctic regions where the tropopause is lower, it is recommended that the fall-winter profile be used.

3.12.6 GENERAL REMARKS ON APPLICABILITY OF THE AEROSOL MODELS

Typical conditions for which the different aerosol models apply as discussed in detail above are summarized in Table 1. However, it must be emphasized that these models only represent a simplified version of typical conditions. It is not practical to include all the details of natural aerosol distributions nor are existing experimental data sufficient to describe the frequency of occurrence of the different conditions. While these aerosol models were developed to be as representative as possibie of different atmospheric conditions, it should be kept in mind that the "rural" aerosol model does not necessarily exactly reproduce the optical properties in a given rural location at a specific time and date, any more than the mid-latitude summer model atmosphere would exactly reproduce the actual temperature and water vapor profiles for that same specific time and location.

4. GEOMETRY

In general, earth curvature has a greater influence on the path length (and hence on the transmittance) than atmospheric refraction. For long slant paths with zenith angles close to 90° in the lower layers of the atmosphere, however, refractive effects can cause a significant increase in the path length (up to 30 percent for a 90° path to space from ground level). Figure 14 shows the effect of atmospheric refraction on defining the minimum height of a path trajectory from space. The minimum height referred to here is also known as the tangent height. In Figure 14 the difference between the geometrical (no refraction) and the actual minimum height is plotted against the actual minimum height for three different model atmospheres. The sketch in the upper right-hand corner of Figure 14 indicates that there is also a discrepancy in the earth center angle β subtended by the trajectory, when refraction is significant. The difference β - β' shown in Figure 14 is equal to the total angular deviation ψ of the trajectory due to refraction.

For many applications it is necessary to account not only for the effect of refraction and earth curvature on the transmittance over a given path trajectory, but also on the purely geometrical aspects of the trajectory itself. For example, the total deviation ψ, angle of arrival ϕ, or angle β subtended by the path trajectory may be required as illustrated in Figure 15. LOWTRAN calculates the quantities

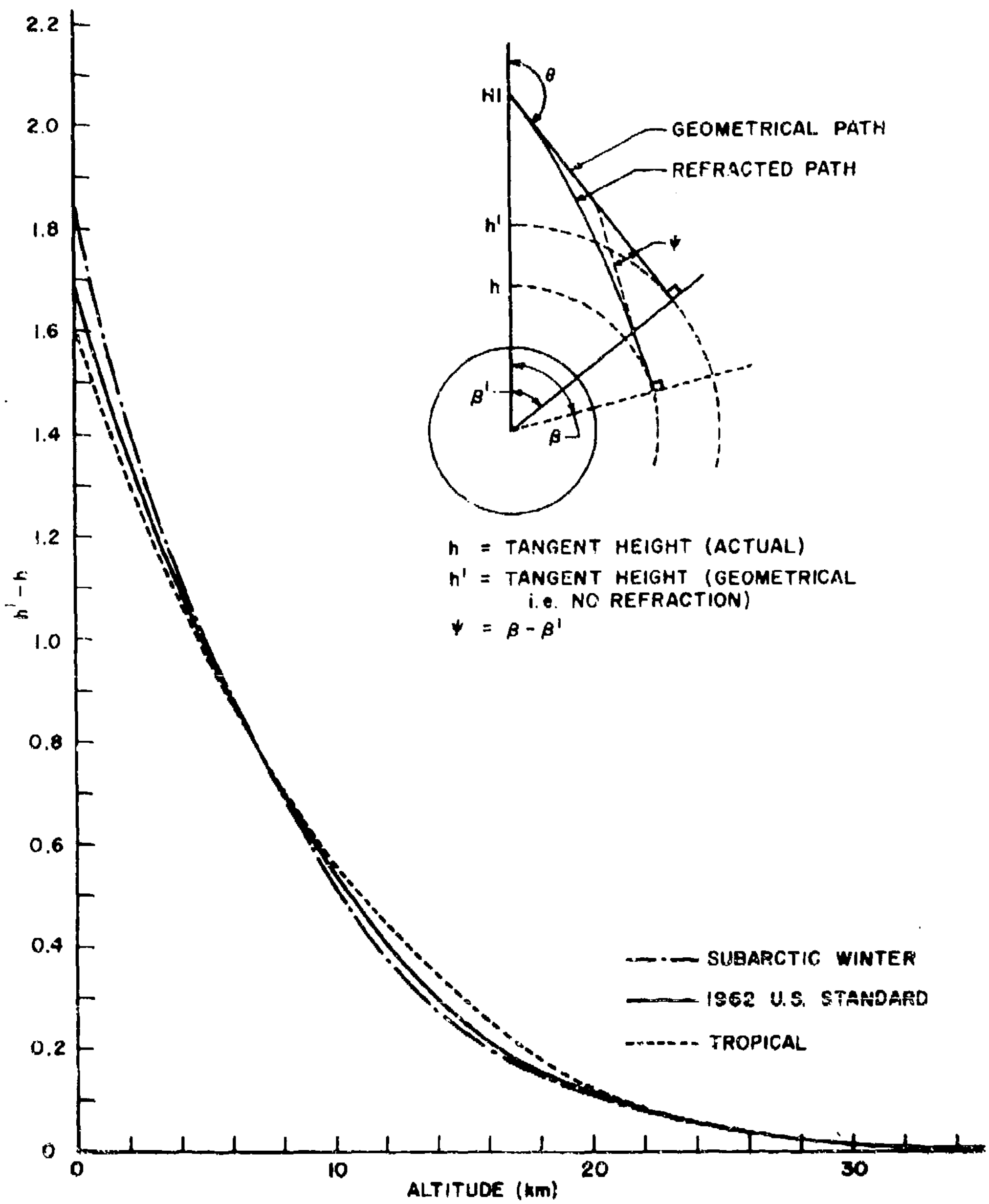

Figure 14. The Difference Between Unrefracted and Refracted Tangent Height Positions as a Function of Altitude for Three Model Atmospheres Based on the 33-Layer Model

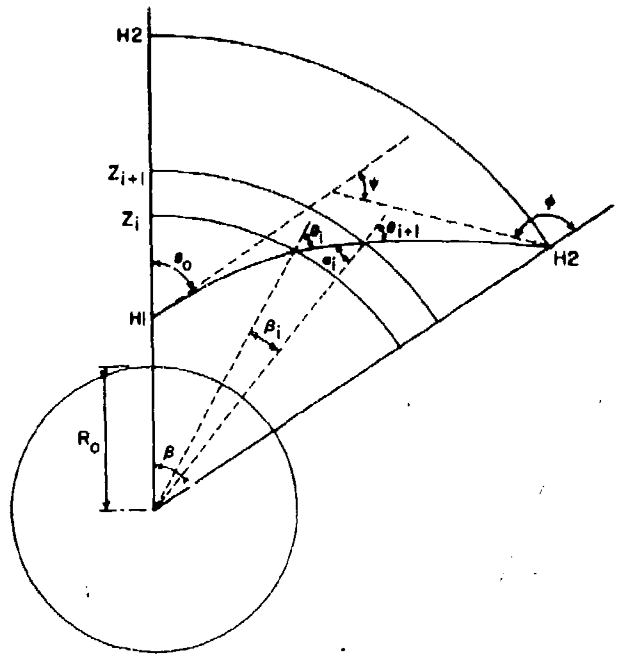

Figure 15. General Schematic of a Refracted Path From Altitudes H1 to H2 Showing the Angles Defining the Trajectory

ψ, ϕ, β and slant range on the basis of a layered atmosphere in the following paragraphs.

The earth's atmosphere is assumed to be divided into a series of concentric spherical layers for each of which a mean refractive index is defined. However, the non-sphericity of the earth is taken into account to some extent by using a different earth radius for each latitude (associated with a given model atmosphere).

Consider the trajectory of a ray passing from heights H1 to H2 at an initial zenith angle θ_o. Let z_i and z_{i+1} define the boundary heights of a given layer, and let θ_i and θ_{i+1} be the local zenith angles at the respective boundaries (see Figure 15). Then at a height of z_{i+1}, the angle of refraction is θ_{i+1}. The angle of incidence α_i at height z_{i+1} can be defined as

$$\sin \alpha_i = (R_o + z_i) \sin \theta_i / (R_o + z_{i+1}) \quad . \tag{1}$$

Applying Snell's law at boundary z_{i+1}, we have

$$n_i \sin \alpha_i = n_{i+1} \sin \theta_{i+1} \tag{2}$$

where n_i and n_{i+1} are the mean refractive indices of the layers above z_i and z_{i+1} respectively.

Substituting for $\sin \alpha_i$ in Eq. (2), we have

$$n_i(R_o + z_i) \sin \theta_i = n_{i+1} (R_o + z_{i+1}) \sin \theta_{i+1} \quad . \tag{3}$$

It follows from symmetry that

$$\begin{aligned} n_i(R_o + z_i) \sin \theta_i &= n_{i-1} (R_o + z_{i-1}) \sin \theta_{i-1} \\ &= n_o (R_o + H1) \sin \theta_o \\ &= \text{const} \quad . \end{aligned} \tag{4}$$

Therefore, the angle of refraction at any level z can be written in terms of the initial input conditions and the refractive index n_o of the layer above H1 as

$$\sin \theta = n_o (R_o + H1) \sin \theta_o / n(R_o + z) \quad . \tag{5}$$

The angle β_i subtended at the center of the earth by the intersection of the ray with the layer z_i to z_{i+1} is given by

$$\beta_i = \theta_i - \alpha_i \quad . \tag{6}$$

Thus the total earth center angle subtended by the ray when traversing the atmosphere from H1 to H2 is

$$\beta = \sum_i^{m-1} (\theta_i - \alpha_i) \tag{7}$$

$$= \sum_i^{m-1} [\sin^{-1} \{A/n_i(R_o + z_i)\} - \sin^{-1} \{A/n_i(R_o + z_{i+1})\}] \tag{8}$$

where m is the number of levels between H1 and H2, and $A = n_o(R_o + H1) \sin \theta_o$.

The angle of arrival ϕ of the ray at H_2 is given by

$$\phi = 180^\circ - \sin^{-1} \{A/n_{m-1}(R_o + H2)\} \quad . \tag{9}$$

The total angular deviation of the trajector ψ is given by

$$\psi = \beta - \phi - \theta_o + 180 \quad . \tag{10}$$

The effective path length between levels z_i and z_{i+1} is given by

$$DS_i = (R_o + z_{i+1}) \sin \beta_i / \sin \theta_i \text{ for } 0^o < \theta < 180^o \tag{11}$$

for $\theta = 0^o$ and 180^o, $DS_i = z_{i+1} - z_i$. If we assume that the equivalent absorber amount per unit path length ω for a given gas varies exponentially with altitude, we can write

$$\int_{z_i}^{z_{i+1}} \omega \, dz = H_i [\omega(z_i) - \omega(z_{i+1})] \tag{12}$$

where $H_i = (z_{i+1} - z_i)/\log_e [\omega(z_i)/\omega(z_{i+1})]$. The amount of absorber W_i along a path of length DS_i between altitudes z_i and z_{i+1} is therefore given by

$$W_i = \int_0^{DS_i} \omega \, ds$$

$$= \frac{DS_i}{z_{i+1} - z_i} \int_{z_i}^{z_{i+1}} \omega \, dz$$

$$= \frac{DS_i [\omega(z_i) - \omega(z_{i+1})]}{\log_e [\omega(z_i)/\omega(z_{i+1})]} \quad . \tag{13}$$

The total equivalent absorber amount W for a given atmosphere path is given by the sum of the W_i values for all layers; that is, $W = \sum_{i=1}^{m-1} W_i$ where m is the number of of levels traversed by the path.

4.1 Refractive Index of Air

The following simplified version of Edlen's[69] expression for the refractive index of air is used in LOWTRAN

$$(n_a - 1)\, 10^{+6} = \left(77.46 + \frac{0.459}{\lambda^2}\right) \frac{P}{T} - \frac{p_{H_2O}}{1013} \left(43.49 - \frac{0.347}{\lambda^2}\right) , \qquad (14)$$

where p_{H_2O} and P refer respectively to the partial pressure of water vapor and atmospheric pressure in millibars, T is atmospheric temperature in degrees Kelvin, and λ is the wavelength in micrometers (μm).

The above expression has been used over the entire wavelength range 0.2 to 28.5 μm in LOWTRAN. Although Edlen's[69] expression for the refractive index of air is widely used in both the visible and infrared spectral regions, it is questionable how far it should be used into the untraviolet and into the far infrared since the formula is based primarily on measurements made in the visible part of the spectrum from 0.43 to 0.8 μm.

4.2 Geometrical Path Configurations

When using LOWTRAN, the type of atmospheric path for which a calculation is to be made must be specified according to one of the three broad categories listed below.

TYPE 1. Horizontal path; that is, a constant pressure path where the effects of earth curvature and refraction are negligible.

TYPE 2. Slant paths between two altitudes from H1 to H2.

TYPE 3. Slant paths to space from initial altitude H1.

The variations within the latter two categories for both upward and downward path trajectories can be seen from Figure 16.

It will be noted that two trajectories are possible for a given set of input parameters, H1, H2, and θ for a downward looking path (TYPE 2), provided that H2 lies between H1 and the minimum height, HMIN.

In most instances, the reader will not be aware that two paths are possible for a given set of input conditions. For such a case, LOWTRAN will execute the shorter path condition (Figure 16d) and print out a message to the effect that the case shown in Figure 16e does exist. Should the reader decide to run the latter case, he need only set the parameter LEN equal to unity and resubmit the case.

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69. Edlen, B. (1966) Metrologia 2:12.

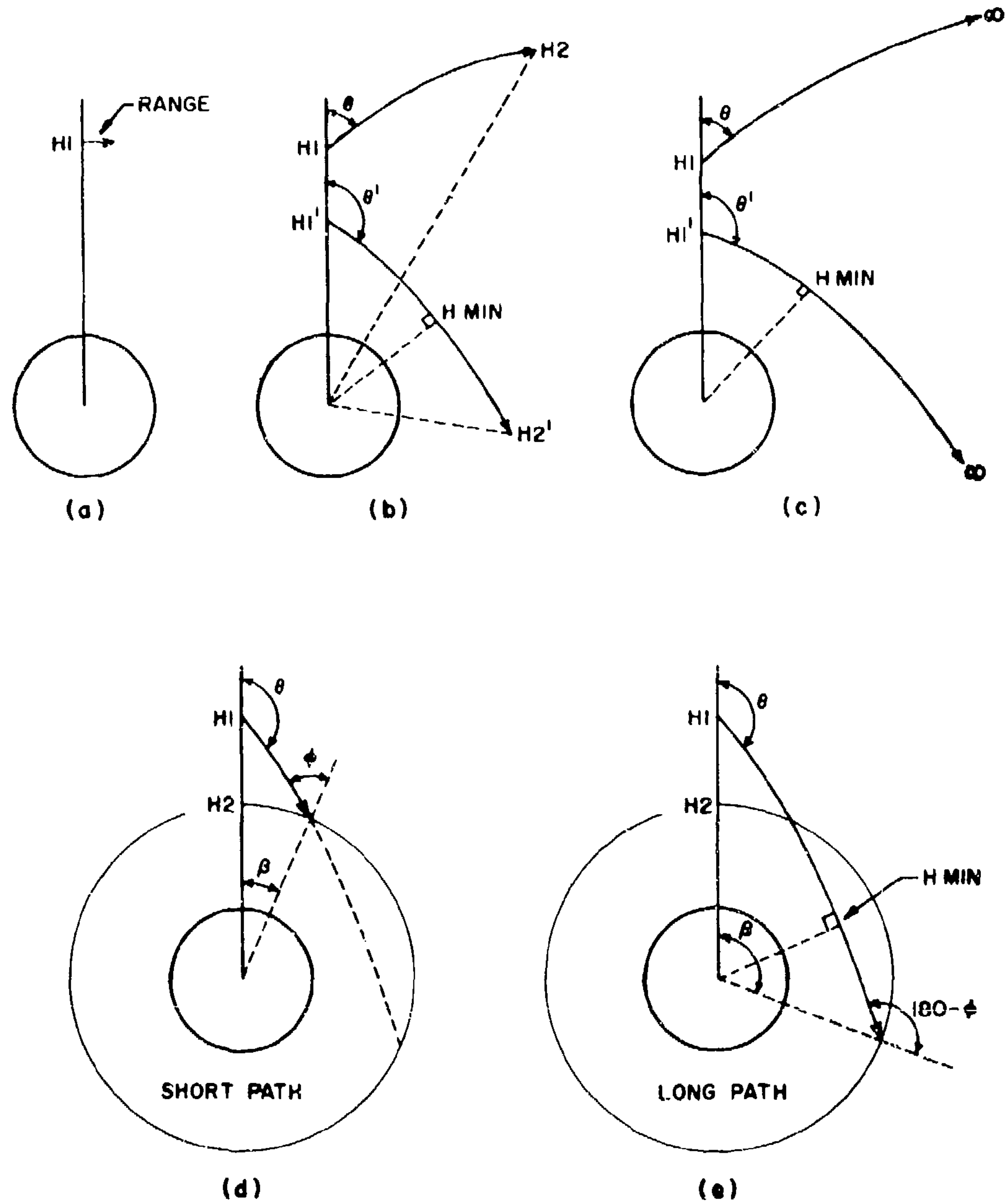

Figure 16. Geometrical Path Configurations: (a) Horizontal Paths, (b) Slant Paths Between Two Altitudes H1 and H2, (c) Slant Paths to Space, (d) A Possible Trajectory for a Downward-Looking Short Path where HMIN < H2 < H1, and (e) A Possible Trajectory for a Downward-Looking Long Path Where HMIN < H2 < H1

5. ATMOSPHERIC TRANSMITTANCE

In the LOWTRAN model, the total atmospheric transmittance at a given wavenumber averaged over a 20-cm^{-1} interval is given by the product of the average transmittances due to molecular band absorption, molecular scattering, aerosol extinction, and molecular continuum absorption. The molecular band absorption is composed of four components; namely the separate transmittances of water vapor, ozone, nitric acid and the uniformly mixed gases (CO_2, N_2O, CH_4, CO, O_2 and N_2).

The average transmittance due to molecular band absorption is represented by a single parameter empirical transmittance function. The argument of the transmittance function is the product of a wavenumber dependent absorption coefficient and "an equivalent absorber amount" for the atmospheric path.

5.1 Molecular Band Transmittance

In the LOWTRAN transmittance model, the average transmittance $\bar{\tau}$ over a 20-cm^{-1} interval (due to molecular absorption) is represented by a single parameter model of the form

$$\bar{\tau} = f(C_\nu \, \omega^* DS) \tag{15}$$

where C_ν is the LOWTRAN wavenumber-dependent absorption coefficient and ω^* is an "equivalent absorber density" for the atmospheric path, DS, defined in terms of the pressure P(z), temperature T(z), concentration of absorber ω and an empirical constant n as follows

$$\omega^* = \omega \left\{ \frac{P(z)}{P_o} \sqrt{\frac{T_o}{T(z)}} \right\}^n \tag{16}$$

where P_o and T_o correspond to STP (1 atm, 273K). If Eq. (16) is substituted in Eq. (15) and n is set to zero and unity, respectively, Eq. (15) reverts to the well-known weak-line and strong-line approximations common to most band models.

The form of the function f and parameter n was determined empirically using both laboratory transmittance data and available molecular line constants. In both cases, the transmittance was degraded in resolution to 20 cm^{-1} throughout the entire spectral range covered here. It was found that the functions f for H_2O and the combined contributions of the uniformly mixed gases were essentially identical, although the parameter n differed in the two cases. Mean values of n were determined to be 0.9 for H_2O, 0.75 for the uniformly mixed gases, and 0.4 for ozone.

Figures 17a, b and c show the LOWTRAN "equivalent absorber densities" given by Eq. (16) and the true absorber densities vs altitude for water vapor, ozone and the uniformly mixed gases. The profiles shown in these figures are for the 1962 U.S. Standard atmosphere, (MODEL = 6).

Figure 18 shows the LOWTRAN empirical transmittance functions defined by Eq. (15) vs the $\log_{10}$ of the effective optical depth ($C_\nu \omega * DS$). The solid function shown is used for water vapor and the uniformly mixed gases.* The dashed function is applicable to ozone.

For sufficiently small values of the argument $C_\nu \omega * DS$, the transmittance functions f were modified for calculations for atmospheric layers of small optical thickness. For cases where ($0.999 \leq \bar{\tau} \leq 1$) the transmittance functions have the analytic form

$$\bar{\tau} = 1 - a\,(C_\nu \omega * DS)^b \tag{17}$$

with a = 0.088 and b = 0.81 for H_2O and the uniformly mixed gases and a = 0.055 and b = 1.03 for ozone. This pseudo-linear approximation in Eq. (17) is used in the computer program for transmittances between 0.999 and 1.

The parameters a and b were determined from a least-squares fit of the empirically derived transmittance function in Eq. (15).

Absorption coefficients for water vapor, ozone, and the combined effects of the uniformly mixed gases, digitized from the spectral curves of McClatchey et al,[6] are included as data for LOWTRAN. The transmittance spectra from which the coefficients were derived were first degraded in resolution to 20 cm^{-1} and the data points were digitized at steps of 5 cm^{-1}. For the ultraviolet and visible ozone bands, the absorption coefficients were digitized at 500 cm^{-1} and 200 cm^{-1} intervals respectively.

The absorption coefficients for water vapor are shown in Figures 19a and b. Figure 19a shows the coefficients in the region from 350 to 5000 cm^{-1} and Figure 19b the region from 4000 to 24,000 cm^{-1}.

Figures 20a, b, and c show the absorption coefficients for ozone. Figure 20a spans the spectral region from 350 to 5000 cm^{-1}, Figure 20b the region from 4000 to 24,000 cm^{-1}, and Figure 20c the region from 20,000 to 50,000 cm^{-1}.

The absorption coefficients for the uniformly mixed gases are shown in Figures 21a and b. The spectral region from 350 to 5000 cm^{-1} is shown in Figure 21a and the region from 4000 to 14,000 cm^{-1} in Figure 21b.

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*Gruenzel[70] has pointed out that in previous versions of LOWTRAN, the value of FW for T = 0.88 was in error. The correct value is 0.4838, not 0.4342.

70. Gruenzel, R.R. (1978) Applied Optics 17:2591.

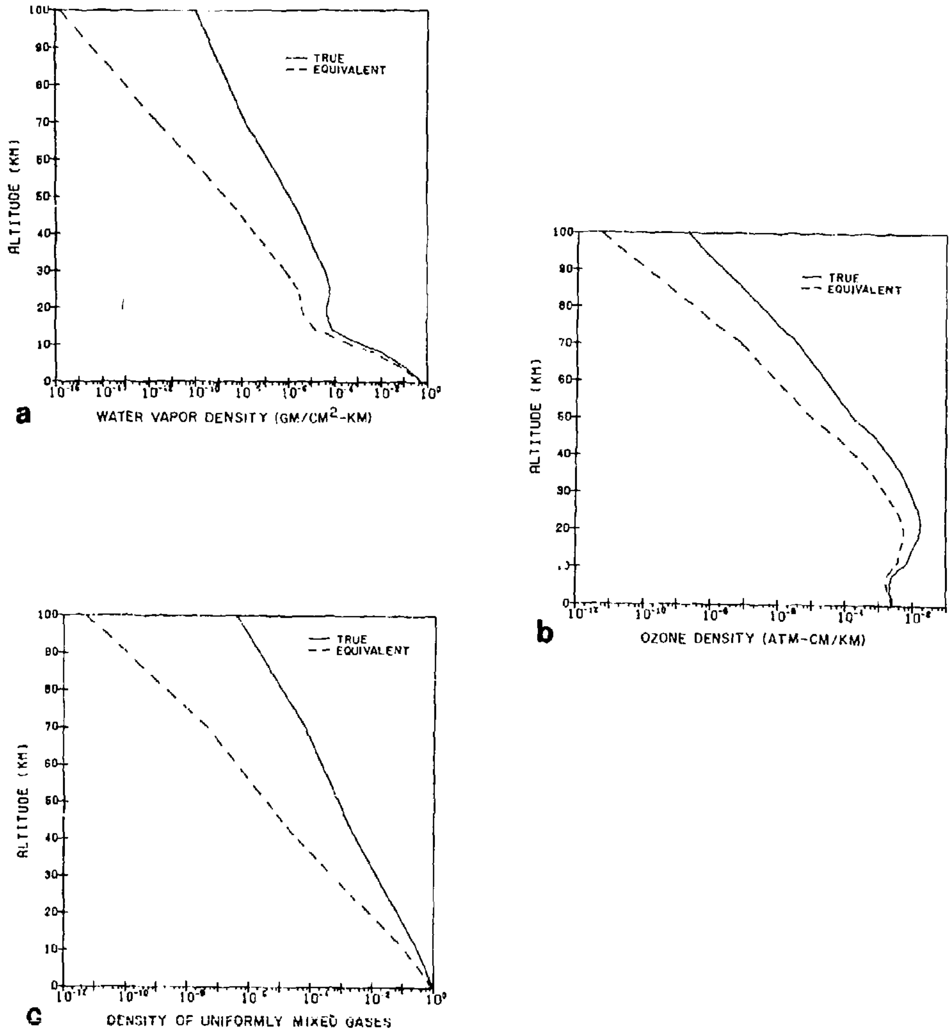

Figure 17. Profiles of True and "Equivalent" Density vs Altitude, 1962 U.S. Standard Atmosphere: a. water vapor, b. ozone, and c. uniformly mixed gases (relative to STP)

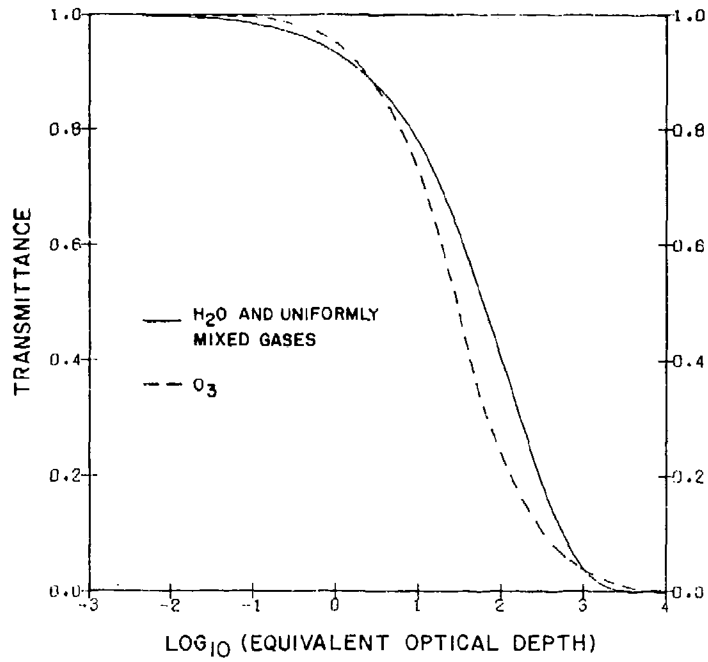

Figure 18. LOWTRAN Empirical Transmittance Functions vs Log_{10} of the Effective Optical Depth ($C_\nu \omega * DS$)

5.2 Nitric Acid

The transmittance due to HNO_3 has been assumed to lie in the weak-line or linear region. Absorption coefficients digitized at 5-cm^{-1} intervals for the 5.9-μm, 7.5-μm, and 11.3-μm bands of HNO_3 have been incorporated into the LOWTRAN program as a subroutine (Subroutine HNO3). These coefficients were obtained by Goldman, Kyle, and Bonomo[71] by fitting their experimental results with the statistical band model approximation, and are shown in Figure 22.

5.3 Nitrogen Continuum Absorption

The continuum due to collision-induced absorption by nitrogen in the 4-μm region, is included in LOWTRAN based on the measurements of Reddy and Cho[72] and Shapiro and Gush[73] (see also McClatchey et al[6]) and is shown in Figure 23.

71. Goldman, A., Kyle, T.G., and Bonomo, F.W. (1971) Statistical band model parameters and integrated intensities for the 5.9-μ, 7.5-μ, and 11.3-μ bands of HNO_3 vapor, Appl. Opt. 1:65.

72. Reddy, S.R., and Cho, C.W. (1965) Canad. J. Physics 43:2331.

73. Shapiro, M.M., and Gush, H.P. (1966) Canad. J. Physics 44:949.

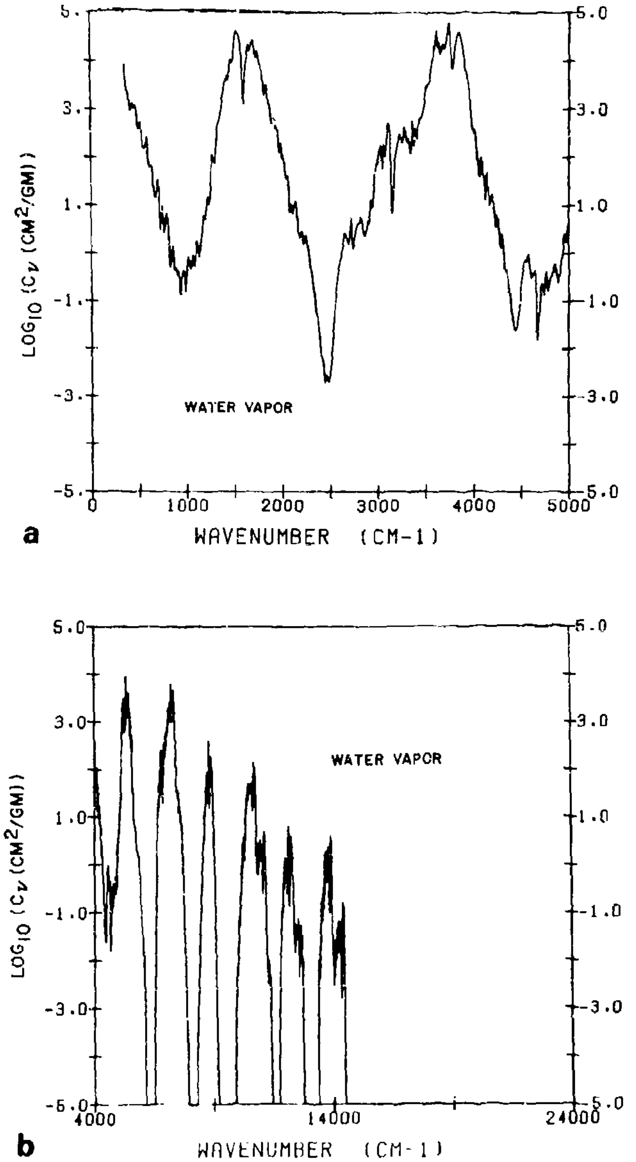

Figure 19. Absorption Coefficient C_ν for Water Vapor: a. from 350 to 5000 cm^{-1}, b. from 4000 to 24,000 cm^{-1}

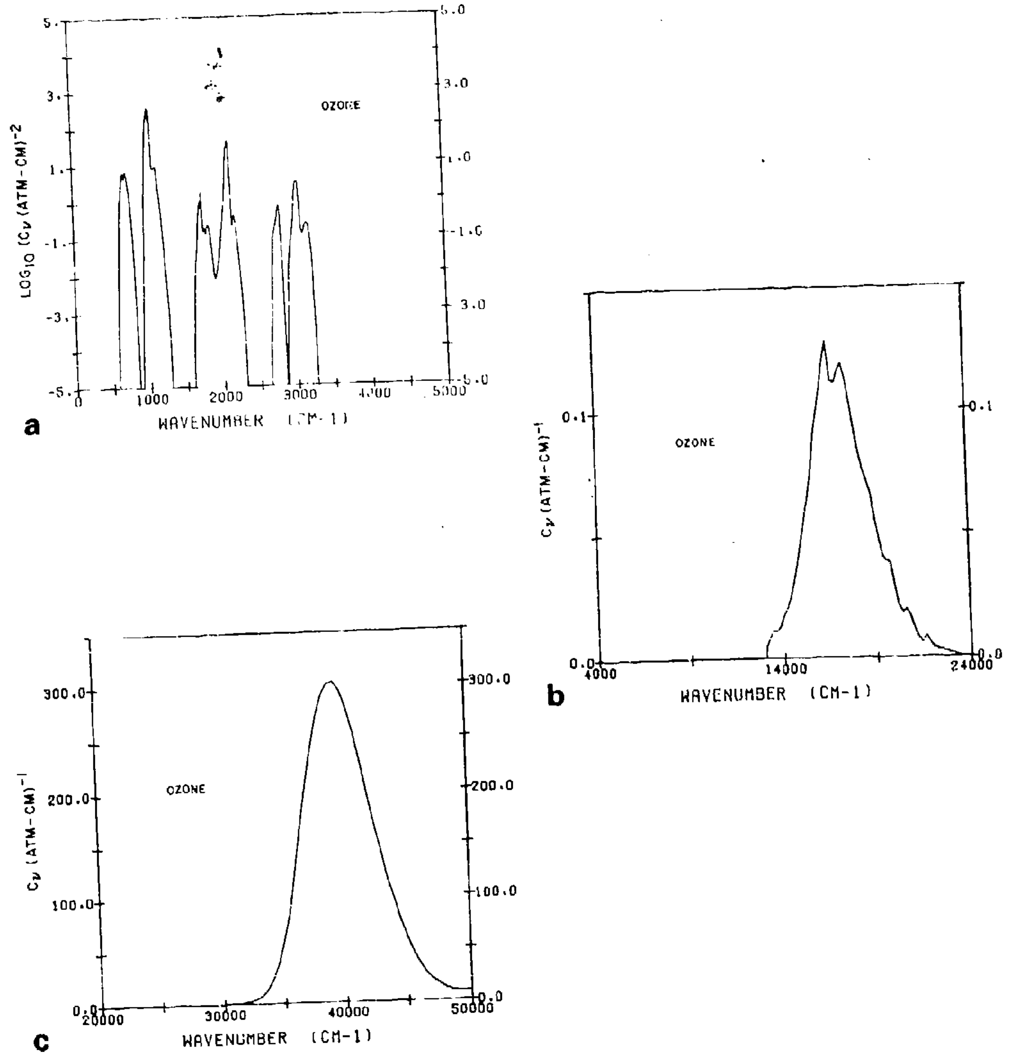

Figure 20. Absorption Coefficient C_ν for Ozone: a. from 350 to 5000 cm^{-1}, b. from 4000 to 24, 000 cm^{-1}, c. from 20, 000 to 50, 000 cm^{-1}

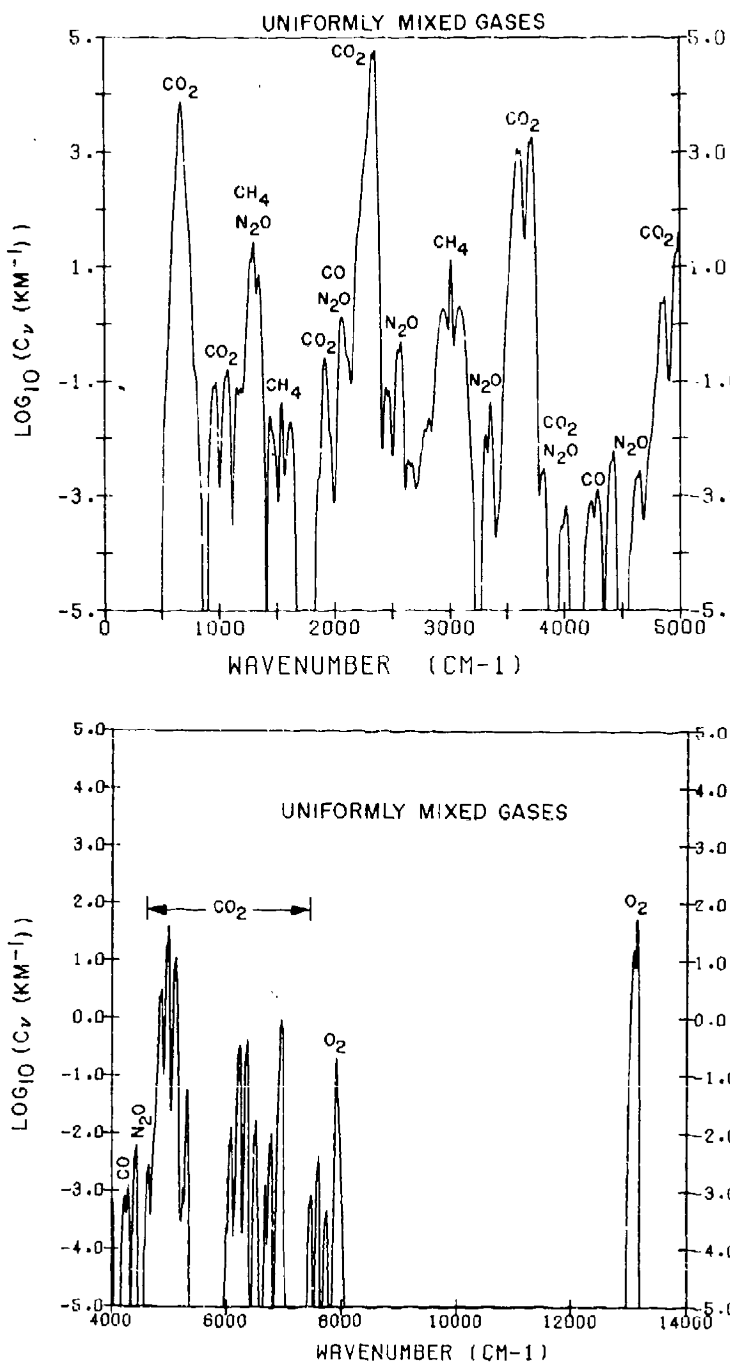

Figure 21. Absorption Coefficient C_ν for the Uniformly Mixed Gases: a. from 350 to 5000 cm^{-1}, b. from 4000 to 14,000 cm^{-1}

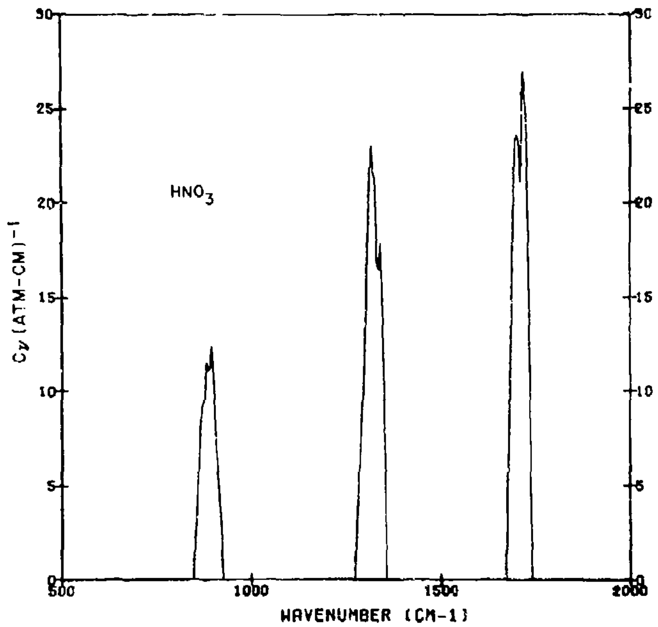

Figure 22. Absorption Coefficient C_ν for Nitric Acid, from 500 to 2000 cm^{-1}

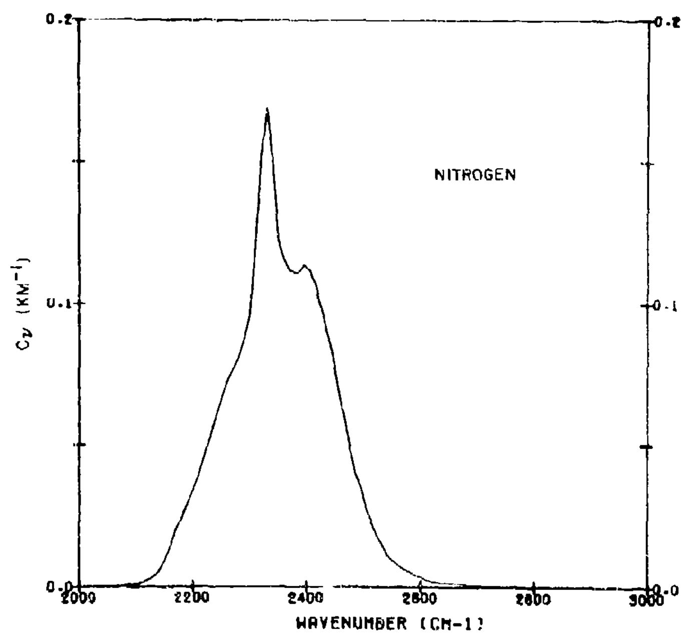

Figure 23. Absorption Coefficient C_ν for the Nitrogen Continuum, from 2000 to 3000 cm^{-1}

The transmittance due to continuum absorption is assumed to follow a simple exponential law.

5.4 Molecular Scattering

The attenuation coefficient (km^{-1}) due to molecular scattering, ABS(6), is introduced into LOWTRAN via the following expression

$$ABS(6) = \nu^4/(9.26799 \times 10^{18} - 1.07123 \times 10^9 \times \nu^2) \tag{18}$$

where ν is in wavenumbers (cm^{-1}). The above expression was obtained from a least-square fit to molecular scattering coefficients published by Penndorf[74] and is shown in Figure 24. This function is a change from the previous LOWTRAN codes and improves the fit in the ultraviolet. The errors in the new function are now less than 1/2 percent from 0.2 to 20 μ.

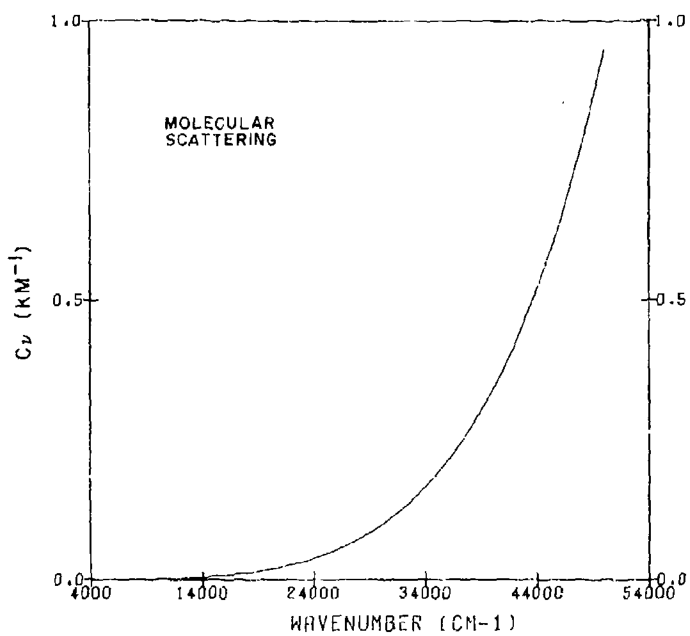

Figure 24. Attenuation Coefficient C_ν Due to Molecular Scattering, from 4000 to 54,000 cm^{-1}

74. Penndorf, R. (1957) Tables of the Refractive Index for Standard Air and the Rayleigh Scattering Coefficient for the Spectral Region between 0.2 and 20 μ and Their Application to Atmospheric Optics, J. Opt. Soc. Amer. 47:176-182.

5.5 Water Vapor Continuum

The attenuation due to the water vapor continuum still eludes a complete theoretical explanation. At present, it appears that it results from the accumulated attenuation of the distant wings of H_2O absorption lines, emanating principally in the far infrared part of the spectrum. This attenuation due to molecular line broadening occurs as a result of collisional interactions between molecules; that is, collisions between two H_2O molecules and those of other gases (principally $H_2O:N_2$ collisions). Other postulates, such as the phenomenon being caused by other absorption mechanisms involving H_2O dimers, remain possibilities yet to be proven.

However, all that can be done at present is to account for the water vapor continuum phenomenon empirically, based on limited experimental measurements, until better line shape theories become available. It should be emphasized that further accurate and well-controlled measurements are urgently required in order to account for this phenomenon in real atmospheric situations with confidence.

The general formulation used to account for the water vapor continuum attenuation at a fixed temperature, has been to define the transmittance $\overline{\tau}(\nu)$ for a path length, DS, as follows

$$\overline{\tau}(\nu) = e^{-k(\nu)DS}$$

where the attenuation coefficient $k(\nu)$ is given by

$$k(\nu) = [C_S P_{H_2O} + C_N(P_T - P_{H_2O})]\,\omega \qquad (19)$$

or

$$k(\nu) = C_S \left[P_{H_2O} + \frac{C_N}{C_S}(P_T - P_{H_2O}) \right] \omega$$

where P_{H_2O} and P_T refer to the water vapor partial pressure and the ambient pressure respectively (atm), and ω defines the quantity of water vapor per unit path length (gm cm^{-2} km^{-1}). The quantities C_S and C_N are generally referred to as the self- and foreign (nitrogen)-broadening coefficients for water vapor.

5.5.1 8- TO 11-μm H_2O CONTINUUM

Recently, a review of available water vapor continuum experimental measurements were made by Roberts et al[75] in the 10-μm region. These workers found

75. Roberts, R.E., Selby, J.E.A., and Biberman, L.M. (1976) Infrared continuum absorption by atmospheric water vapor in the 8-12 μm window, Applied Optics 14:2085.

that an empirical expression of the form given in Eq. (20) (below), provided a good fit to the wavenumber dependence of the measured water vapor continuum attenuation coefficients at 296 K. Also, the water vapor continuum attenuation coefficient has been found to have a significant temperature dependence. Based on the laboratory measurements of Burch[76] using samples of water vapor at elevated temperatures, an approximate empirical expression was obtained by Roberts et al[75] for the temperature dependence which is given in Eq. (21) below. It was found that the attenuation coefficient due to the water vapor continuum increases as the temperature decreases. That is, for a fixed amount of water vapor in a given path, one would expect more absorption at colder temperatures and less absorption at warmer temperatures. This is a somewhat unusual phenomenon. In practice one finds less water vapor in the atmosphere under cold conditions, therefore, the effect of temperature on the attenuation in the 8- to 14-μm region plays two competing roles, through the total water content of the path and the attenuation coefficient.

The empirical fits to the wavenumber and temperature dependence of the water vapor continuum described in Roberts et al[75] have been used in LOWTRAN with the appropriate conversion of units, as follows:

The attenuation coefficient C_s gm^{-1} cm^{+2} atm^{-1} at 296 K is given by the following expression in the 8- to 14-μm region

$$C_s(\nu,\ 296) = 4.18 + 5578 \exp\left(-7.87 \times 10^{-3}\ \nu\right) \tag{20}$$

where ν is the wavenumber in cm^{-1} (note that $\nu = 10^4/\lambda$, where λ is the wavelength in μm).

Figure 25a shows a plot of $C_s(\nu,\ 296)$ vs wavenumber in the 8- to 14-μm region.

The temperature dependence of the coefficient C_s was found to vary as

$$C_s(\nu, T) = C_s(\nu,\ 296) \exp\left[1800\ \left(\frac{1}{T} - \frac{1}{296}\right)\right] \tag{21}$$

where T is the temperature in degrees Kelvin.

Equation (21) can be rewritten as follows

$$C_s(\nu, T) = C_s(\nu,\ 296) \exp\ \left[6.08\ \left(\frac{296}{T} - 1\right)\right] \quad . \tag{22}$$

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76. Burch, D. E. (1970) Semiannual Technical Report: Investigation of the Absorption of Infrared Radiation by Atmospheric Gases, Aeronutronic Report U-4784, ASTLA (AD 702117).

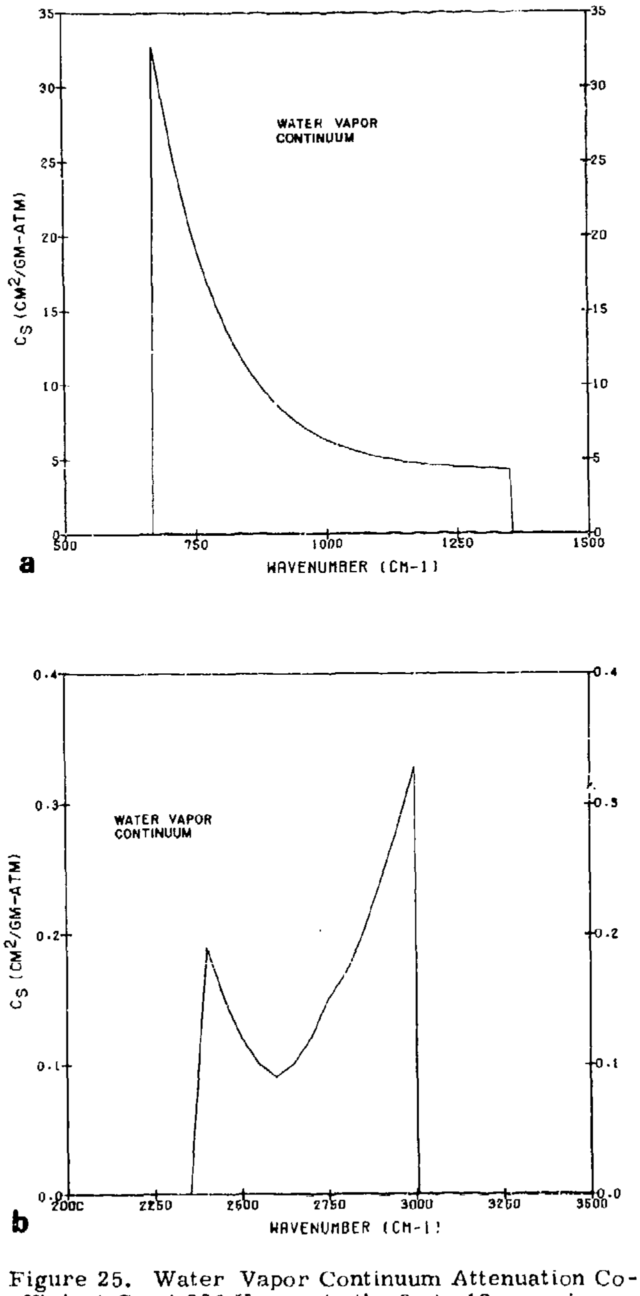

Figure 25. Water Vapor Continuum Attenuation Coefficient C_s at 296 K: a. in the 8- to 12-μ region, b. in the 3.5- to 4.2-μ region

The second term in Eq. (19), defined as C_N/C_S, represents the ratio of the foreign (nitrogen)-broadening coefficient to the self-broadening coefficient.

In LOWTRAN, a value at 296 K of 0.002 for the parameter C_N/C_S is used, based on the review of the measurements. It is assumed that C_N/C_S does not vary with temperature (since no supporting measurements are available).

The transmittance due to the water vapor continuum in the 8- to 14-μm region is calculated for a horizontal path of length DS (km) at altitude z using the following expression in LOWTRAN

$$\bar{\tau}(\nu) = \exp\,[-\,C_s(\nu,\ 296)W(z)DS] \tag{23}$$

where W(z) is the effective H_2O absorber amount per unit path lengh (in gm cm^{-2} atm km^{-1}) at altitude z, and C_s $(\nu,\ 296)$ is the water vapor (self-broadened) attenuation coefficient obtained from laboratory measurements at a temperature of 296 K.

The quantity W(z) is given by

$$W(z) = w(z)\ \left\{P_{H_2O}\ \exp\left[6.08\left(\frac{296}{T(z)} - 1\right)\right] + 0.002\,(P_T - P_{H_2O})\right\} \tag{24}$$

where

$w(z)$ = gm cm^{-2}/km of H_2O in the path at temperature T,

P_{H_2O} = H_2O partial pressure (atm) at altitude z,

P_T = ambient (total) pressure (atm) at altitude z, and

$T(z)$ = ambient temperature at altitude z (degrees Kelvin).

Note that the temperature dependence of the attenuation coefficient $C_s(\nu, T)$ given in Eq. (22) has been incorporated into the expression for W in Eq. (24). The reason for this is so that the temperature variation over a given atmospheric slant path is weighted equally with the water content along the path.

5.5.2 3.5- TO 4.2-μm H_2O CONTINUUM

Using the laboratory measurements of Burch et al,[77] an empirical expression was obtained for the temperature dependence of the attenuation coefficients in the 3- to 5-μm region. The measurements reported in Burch et al[77] were for samples of pure water vapor made at elevated temperatures, and have been confirmed independently by White et al.[78]

77. Burch, D.E., Gryvnak, D.A., and Pembrook, J.D. (1971) Philco Ford Corp. Aeronutronic Report U-4897, ASTIA (AD 882876).

78. White, K.O., Watkins, W.R., Tuer, T.W., Smith, F.G., and Meredith, R.E. (1975) J. Opt. Soc. Amer. 65:1201.

It was found that

$$C_s(\nu, T) = C_s(\nu,\ 296)\ \exp\ \left[4.56\ \left(\frac{296}{T} - 1\right)\right] \tag{25}$$

provides an approximate fit to the measurements for pure water vapor extrapolated to a temperature of 296 K.

The attenuation coefficients at 296 K used in LOWTRAN for the 3.4- to 4.2-μm region have been digitized directly from the extrapolations reported by Burch et al,[77] and are shown in Figure 25b.

From the limited measurements available, it appears that the temperature dependence of the water vapor continuum (due to self broadening) in the 3.5- to 4.2-μm region is not as strong as that in the 8- to 14-μm region.

A value for the nitrogen-broadening coefficient of 0.12 was obtained by Burch et al[77] for a temperature of 428 K. Since no other measurements are available at the time of writing, this value will be used in LOWTRAN with the same temperature correction as is applied to the self-broadening term (see Eq. (26)).

As for the 8- to 14-μm region, the transmittance for a horizontal path of length DS (km) can be calculated using Eq. (23), where the parameter W(z) is now given by the following expression for the 3.5- to 4.2-μm region

$$W(z) = w(z)\ \left[P_{H_2O} + 0.12\ (P_T - P_{H_2O})\right]\ \exp\ \left[4.56\ \left(\frac{296}{T(z)} - 1\right)\right] \tag{26}$$

As in Eq. (24), the temperature dependence of the attenuation coefficient has been incorporated into Eq. (26). It will be noted that the nitrogen-broadening coefficient in the 4-μm region is more significant relative to the self-broadening term than in the 10-μm region. Again it should be emphasized that the above expressions are approximate and further measurements are required to determine the temperature dependence of the nitrogen-broadening coefficient, as well as more accurate values for the wavelength dependence of the self-broadening coefficient at ambient temperatures (for example, 296 K) and its temperature dependence.

5.6 Aerosol Transmittance

Within a given atmospheric layer of path length, DS, in km, the transmittance, $\overline{\tau}(\nu)$, due to aerosol extinction is given by

$$\overline{\tau}(\nu) = \mathrm{EXP}\ [-\mathrm{EXTV}(\nu) \times \mathrm{HAZE} \times \mathrm{DS}] \tag{27}$$

where EXTV(ν) is the normalized extinction coefficient for the wavenumber ν of the appropriate aerosol model and altitude. HAZE is the aerosol scaling factor (see Section 3).

EXTV(ν) is found by interpolation of the values stored in the code for the required wavenumber and relative humidity. HAZE is determined by interpolation of the appropriate aerosol scaling factor profiles according to the meteorological range and season.

6. ATMOSPHERIC RADIANCE

The LOWTRAN program has the option to calculate atmospheric and earth radiance. A numerical evaluation of the integral form of the equation of radiative transfer is used in the program. The emission from aerosols and the treatment of aerosol and molecular scattering is considered only in the zeroth order. Additional contributions to atmospheric emission from radiation scattered one or more times are neglected. Local thermodynamic equilibrium is assumed in the atmosphere.

The average atmospheric radiance (over a 20-cm^{-1} interval) at the wavenumber, ν, along a given line-of-sight in terms of the LOWTRAN transmittance parameters is given by

$$I(\nu) = \int_{\bar{\tau}_a^b}^{1} d\bar{\tau}_a \, B(\nu, T)\, \bar{\tau}_s + B(\nu, T_b)\, \bar{\tau}_t^b \tag{28}$$

where the integral represents the atmospheric contribution and the second term is the contribution of the boundary, (for example, the surface of the earth or a cloud top) and

$\bar{\tau}_a$ = average transmittance due to absorption,

$\bar{\tau}_s$ = average transmittance due to scattering,

$\bar{\tau}_t = \bar{\tau}_a \bar{\tau}_s$ = average total transmittance,

$\bar{\tau}_a^b, \bar{\tau}_t^b$ = average total transmittances from the observer to boundary,

$B(\nu, T)$ = average Planck (blackbody) function corresponding to the frequency ν and the temperature T of an atmospheric layer.

T_b = temperature of the boundary.

The emissivity of the boundary is assumed to be unity.

The LOWTRAN band model approach used here assumes that since the blackbody function is a slowly varying function of frequency we can represent the average value of the radiance in terms of the average values of the transmittance and the blackbody function. $\bar{\tau}_a$, $\bar{\tau}_s$, and $\bar{\tau}_t$ vary from 1 to $\bar{\tau}_a^b$, $\bar{\tau}_s^b$, and $\bar{\tau}_t^b$ along the observer's

line-of-sight. For lines of sight which do not intersect the earth or a cloud layer, the second term in Eq. (28) is omitted.

The numerical analogue to Eq. (28) has been incorporated in the LOWTRAN computer program. The numerical integration of the radiance along a line-of-sight for a given model atmosphere defined at N levels is given by

$$I(\nu) = \sum_{i=1}^{N-1} (\overline{\tau}_a(i) - \overline{\tau}_a(i+1))\, B\left(\nu, \frac{T(i) + T(i+1)}{2}\right)\left(\frac{\overline{\tau}_s(i) + \overline{\tau}_s(i+1)}{2}\right)$$

$$+ B(\nu, T_b)\overline{\tau}_t^b \quad . \qquad (29)$$

Thus, the spectral radiance from a given atmospheric slant path (line-of-sight) can be calculated by dividing the atmosphere into a series of isothermal layers and summing the radiance contributions from each of the layers along the line-of-sight, that is, numerically evaluating Eq. (28). This can be clearly seen from the following simple example.

Neglecting scattering, consider a three-layered atmosphere characterized by temperatures T_1, T_2, and T_3 as shown in Figure 26. Let $\overline{\tau}_1$, $\overline{\tau}_2$, and $\overline{\tau}_3$ be the transmittances from the ground to the boundaries of each of the layers respectively (see Figure 26a). Figure 26b shows the corresponding case for an observer in space (distinguished by primed $\overline{\tau}$ values). Then from Eq. (29) the total downward spectral radiance for an observer on the ground (looking upwards) is given by

$$I(\nu)\downarrow = (1 - \overline{\tau}_1)B(\nu, T_1) + (\overline{\tau}_1 - \overline{\tau}_2)B(\nu, T_2) + (\overline{\tau}_2 - \overline{\tau}_3)B(\nu, T_3) \quad . \qquad (30)$$

Similarly for an observer looking down from the top of the atmosphere (see Figure 26b), the total upward spectral radiance is given by

$$I(\nu)\uparrow = (1 - \tau_1')B(\nu, T_3) + (\tau_1' - \tau_2')B(\nu, T_2) + (\tau_2' - \tau_3')B(\nu, T_1) + \tau_3'\, B(\nu, T_b) \quad . \qquad (31)$$

A comparison of Eqs. (30) and (31) shows that in addition to the boundary contributions to the total upward spectral radiance, the total downward and the total upward spectral radiances from the same atmospheric layers are not the same but depend on the position of the observer relative to a given atmospheric slant path. In the LOWTRAN radiance program, the position of the observer is always defined by the input parameter, H1.

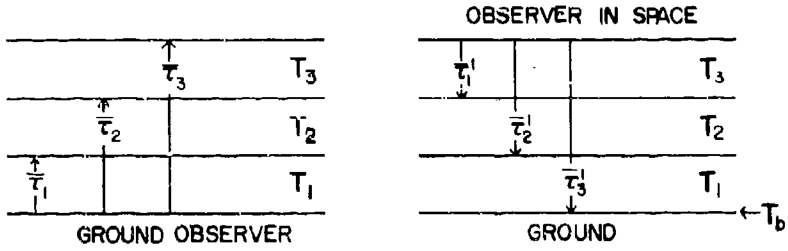

Figure 26. Upward and Downward Atmospheric Paths Through a Three-Layered Atmosphere for Radiance Calculations

It should be emphasized that in the calculation of radiance as given by Eq. (28), scattering is treated only as a loss mechanism and is not included as a source.

In a recent paper by Ben-Shalom et al,[79] it has been noted that for certain atmospheric paths of high optical depth where multiple-scattered radiation is significant, the algorithm used in LOWTRAN underestimates the background radiation. The authors have proposed a "conservative scattering" solution for these cases where only the total extinction is used for the radiative transfer calculations. However, no assessment of the validity of the "conservative scattering" method proposed vs the "zero scattering" algorithm in LOWTRAN for the various paths encountered in the atmosphere has been made.

Until a general multiple-scattering solution for radiative transfer is available in the code, it is recommended that users of LOWTRAN examine the scattering contribution along a given atmospheric path. For scattering in the linear region, the present LOWTRAN algorithm should be appropriate. For high-scattering conditions, users might consider modifying the radiance algorithm as Ben-Shalom et al[79] have proposed.

7. PROGRAM STRUCTURE

In addition to the inclusion of new aerosol models and new aerosol extinction coefficients into the LOWTRAN code, extensive reprograming of the code has been made for improved logical flow of the program and user understanding. As shown in Figure 27, the LOWTRAN code structure consists of a main program, LOWEM, and 19 subroutines. A listing of the code is given in Appendix A. The data file,

79. Ben-Shalom, A., Barzilia, B., Cabib, D., Devir, A.D., Lipson, S.G., and Oppenheim, U.P. (1980) Applied Optics Vol. 19, No. 6, p. 838.

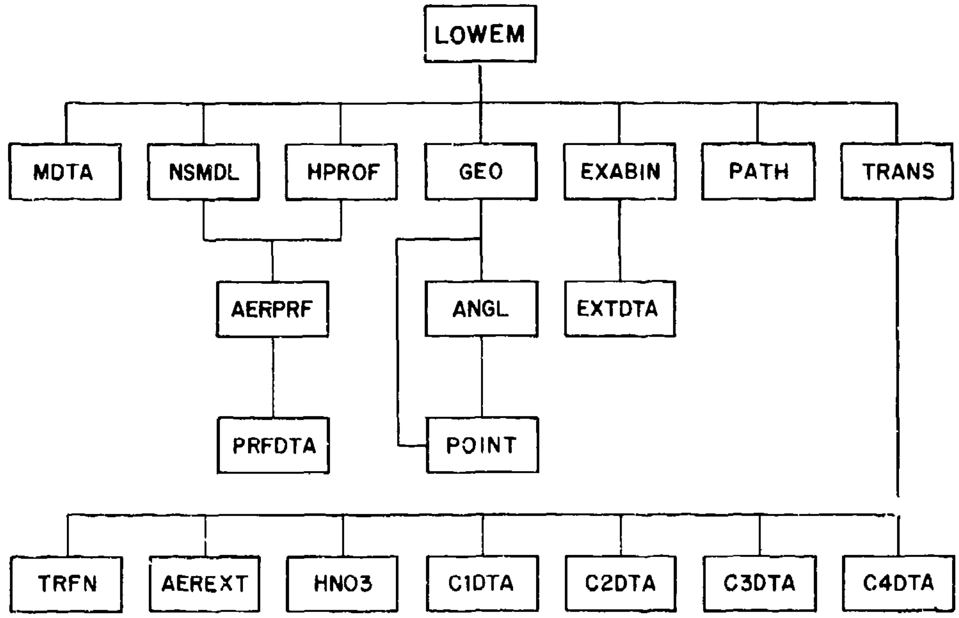

Figure 27. LOWTRAN Program Structure

TAPE5, used in previous LOWTRAN codes has been eliminated. The information from this file has been incorporated into the code in data statements.

In the main program, LOWEM, four control cards are read in for standard execution of the code. New aerosol control parameters have been added to these cards, as will be explained in the instructions for using the code in Section 8.

The transmittance and radiance output tables are also written to the mass storage file, TAPE7, declared on the PROGRAM LOWEM card. The subroutines, MDTA, NSMDL, HPROF, GEO, EXABIN, PATH, and TRANS are called from the main program. A definition of symbols in PROGRAM LOWEM is given in Appendix B.

Subroutine MDTA, called from the main program, contains the altitudes, pressure, temperature, water vapor and ozone density profiles of the six model atmospheres. The nitric acid volume mixing ratio profile is also stored in the subroutine.

Subroutine NSMDL is called from the main program for user defined model atmospheres or aerosol models (MODEL = 0 or MODEL = 7). The input cards and options for the user defined models are explained in Section 8. Subroutine AERPRF is called from this subroutine.

Subroutine HPROF, called from the main program, sets up the appropriate HORIZONTAL PROFILES of molecular and aerosol-absorber densities in LOWTRAN units, using either the model data from MDTA or the user-defined model data from NSMDL. Subroutine AERPRF is also called from this subroutine.

Subroutine AERPRF, called from either NSMDL or HPROF, sets up the appropriate aerosol HORIZONTAL PROFILES for the model selected. Subroutine PRFDTA, called from AERPRF, contains the altitude-dependent profiles of the aerosol models allowed by the program, stored in data statements.

Subroutine GEO, called from the main program, is the spherical geometry subroutine, with correction for refraction, used to calculate the absorber amounts along the atmospheric slant path. The VERTICAL PROFILES and the equivalent absorber amounts are determined in this subroutine. The matrix, WLAY, is also defined in this subroutine for use with subroutine PATH, for radiance calculations. Subroutine ANGL and POINT are called from this subroutine.

Subroutine ANGL is called from GEO to calculate the initial zenith angle for the atmospheric slant path, when the initial and final altitudes and the earth center angle are specified. Subroutine POINT is also called from ANGL.

Subroutine POINT, called from GEO and ANGL, is used to compute the mean refractive index above and below a given altitude and to interpolate exponentially the equivalent absorber densities at that altitude.

Subroutine EXABIN is called from the main program to load the extinction and absorption coefficients for the four aerosol altitude regions appropriate to the aerosol model selected by the user. Interpolation of the boundary layer aerosol coefficients based on relative humidity is performed in this subroutine. Subroutine EXTDTA is called from EXABIN.

The aerosol extinction and absorption coefficients and wavelengths of all the aerosol models are stored in subroutine EXTDTA, called from EXABIN.

Subroutine PATH, called from the main program for radiance calculations, loads the cumulative absorber amounts along the atmospheric slant path into the matrix, WPATH. This data is transferred to PATH from GEO through the vertical profile matrix, WLAY.

Subroutine TRANS, called from the main program, calculates the transmittance and radiance between the wavenumbers, V1 and V2, in steps of DV for the atmospheric slant path. Subroutines TRFN, AEREXT, HNO3, C1DTA, C2DTA, C3DTA, and C4DTA are called by TRANS.

The LOWTRAN transmittance functions for water vapor, ozone, and the uniformly mixed gases are stored in data statements in subroutine TRFN.

Subroutine AEREXT interpolates the aerosol extinction coefficients for the four altitude regions to obtain the proper values at the wavenumber, ν.

Subroutine HNO3 determines the nitric acid absorption coefficient at the wavenumber, ν, from the arrays stored in the subroutine.

The molecular water vapor absorption coefficient is determined at a specified wavenumber from the array, C1, stored in subroutine C1DTA.

The absorption coefficient for the uniformly mixed gases at a specified wavenumber is determined from the array, C2, stored in subroutine C2DTA.

The infrared absorption coefficient for ozone at the wavenumber, ν, is obtained from the array, C3, stored in subroutine C3DTA.

Subroutine C4DTA, called from TRANS, contains data arrays for the nitrogen continuum absorption (C4), the 4-μm water vapor continuum absorption (C5), and the ozone ultra-violet and visible absorption (C8).

With the new code structured into subroutines, the program has been run on the AFGL CDC6600, using segment loading of computer code to reduce central memory storage requirements. A load map using the segment option is shown in Appendix C.

With segment loading of the code, the core storage requirements for execution are reduced by approximately a factor of two over conventional loading of the program. Similar type segment loading of the LOWTRAN code would allow possible use of the code on minicomputers.

8. INSTRUCTIONS FOR USING LOWTRAN 5

The instructions for using LOWTRAN 5 are similar to those for previous LOWTRAN codes. New control parameters defining the aerosol profiles and extinction coefficients have been added to the first input card. Changes have also been made in the input of aerosol models in user-defined atmospheres (MODEL = 7). As mentioned previously, the data file, TAPE 5, has been eliminated and made part of the Fortran code.

In general, for standard atmospheric models, only four input cards are required to run the program for a given problem. The formats for these four cards and definitions of the input parameters on these cards are given below.

8.1 Input Data and Formats

The data necessary to specify a given problem are given on the four cards as follows:

CARD 1 MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS

FORMAT (11I3, 2F10.3, 2I3, F10.3)

CARD 2 H1, H2, ANGLE, RANGE, BETA

FORMAT (5F10.3)

CARD 3	V1, V2, DV	FORMAT (3F10.3)
CARD 4	IXY	FORMAT (I3)

Definitions of the above quantities will be discussed in Section 8.2.

If the quantity MODEL given in CARD 1 is set equal to 0 or 7 (which is the case if meteorological data are used as input to the program), then the above card sequence (and format for CARD 2) is changed. These cases will be described in Section 8.3.

8.2 Basic Instructions

The various quantities to be specified on each of the four control cards (summarized in Section 8.1) will be discussed in this section.

8.2.1 CARD 1 – MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS

The parameter MODEL selects one of six geographical model atmospheres or specifies that user-defined meteorological data are to be useu in place of the standard models. ITYPE and LEN determine one of three types of atmospheric paths for a given problem. JP is a user option to suppress printing of profiles and tables in the output. IEMISS selects the mode of program execution (transmittance or radiance). IM, M1, M2, M3, ML, RO, and TBOUND are additional input parameters for non-standard cases. IHAZE, ISEASN, IVULCN, and VIS are control parameters used to select the profiles and types of extinction coefficients for the aerosol models (N.B. VIS is now specified on CARD1).

MODEL = 0 if meteorological data are specified (for horizontal paths only)*.
= 1 selects TROPICAL MODEL ATMOSPHERE.
= 2 selects MIDLATITUDE SUMMER.
= 3 selects MIDLATITUDE WINTER.
= 4 selects SUBARCTIC SUMMER.
= 5 selects SUBARCTIC WINTER.
= 6 selects 1962 U.S. STANDARD
= 7 if a new model atmosphere (or radiosonde data) is to be inserted.

ITYPE = 1 for a horizontal (constant-pressure) path.
= 2 for a vertical or slant path between two altitudes.
= 3 for a vertical or slant path to space.

The TYPE 1 path should not be confused with a long 90° path where the local height of the end of the trajectory is at a significantly different height. In such a case, specify the path according to ITYPE = 2.

*In these cases the format for Card 2 changes (see non-standard conditions, Section 8.3).

LEN = 0 for normal operation of program.

= 1 selects the downward TYPE 2 LONG path.

The parameter LEN can be ignored (that is, left blank) for the majority of cases. It need only be used for a downward-looking path (H2 < H1) when two paths are possible for the same input parameters. In such a case, a computer printout statement will be given indicating that the user has two choices for the problem and that the shorter path has been executed. Set LEN = 1 for the longer case.

JP = 0 for normal operation of program.

= 1 to suppress printing of transmittance table/or radiance table and horizontal and vertical profiles.

The control parameter, IEMISS, determines the mode of execution of the program.

IEMISS = 0 for program execution in transmittance mode.

= 1 for program execution in radiance mode.

A message is printed to the user on the output file indicating the mode of program execution.

Table 2A summarizes the use of these five control parameters specified on CARD1. For non-standard cases, provision is made on CARD1 for additional user options with the parameters IM, M1, M2, M3, ML, RO, and TBOUND.

IM = 0 for normal operation of program or when <u>subsequent</u> calculations are to be run with MODEL = 7.

= 1 when radiosonde data are to be read in <u>initially</u>.

ML = Number of levels to be read in for MODEL = 7.

Note that IM and ML are only used when MODEL = 7 and then only on the first calculations when the data are read in.

M1 = M2 = M3 = 0 for normal operation of program.

The parameters M1, M2, and M3 can each take integer values between 0 and 6 and are used to modify or supplement the altitude profiles of temperature and pressure, water vapor, and ozone respectively, for any given atmospheric model specified by MODEL.

For example:

M1 = 1 selects the TROPICAL <u>temperature</u> and <u>pressure</u> altitude profiles.

= 2 selects the MIDLATITUDE SUMMER <u>temperature</u> and <u>pressure</u> altitude profiles.

= 6 selects the 1962 U.S. STANDARD <u>temperature</u> and <u>pressure</u> altitude profiles.

M2 = 1 selects the TROPICAL <u>water vapor</u> altitude profile.

= 2 selects the MIDLATITUDE SUMMER <u>water vapor</u> altitude profile.

= 6 selects the 1962 U.S. STANDARD <u>water vapor</u> altitude profile.

Table 2a. LOWTRAN CARD 1 Input Parameters: MODEL, ITYPE, LEN, JP, IEMISS

CARD 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS FORMAT (11I3, 2F10.3, 2I3, F10.3)									
COL 3	MODEL	COL 9	ITYPE	COL 12	LEN	COL 15	JP	COL 33	IEMISS
0	USER * DEFINED	1	HORIZONTAL PATH	0	SHORT PATH	0	NORMAL OUTPUT	0	TRANS-MITTANCE
1	TROPICAL	2	SLANT PATH H1 TO H2	1	LONG PATH	1	SHORT OUTPUT	1	RADIANCE
2	MIDLATITUDE SUMMER	3	SLANT PATH H1 TO SPACE						
3	MIDLATITUDE WINTER								
4	SUBARCTIC SUMMER								
5	SUBARCTIC WINTER								
6	1962 U.S. STANDARD								
7	USER * DEFINED								

* OPTIONS FOR NON-STANDARD MODELS

IM, M1, M2, M3, ML, RO, TBOUND LEFT BLANK FOR STANDARD CASES
REFER TO TEXT FOR NON-STANDARD CASES

M3 = 1 selects the TROPICAL ozone altitude profile.
= 2 selects the MIDLATITUDE SUMMER ozone altitude profile.
= 6 selects the 1962 U.S. STANDARD ozone altitude profile.

RO = radius of the earth (km) at the particular geographical location at which the calculation is to be performed.

If RO is left blank, the program will use the midlatitude value of 6371.23 km if MODEL is set equal to 0 or 7. Otherwise the earth radius for the appropriate standard model atmosphere (specified by MODEL) will be used.

TBOUND = temperature of the earth (^{o}K) at the location at which the calculation is to be performed.

TBOUND is only used in the radiance mode of the program for slant paths which intersect the earth. If TBOUND is left blank, the program will use the temperature of the first atmospheric layer as the boundary temperature.

IHAZE, ISEASN, IVULCN, and VIS select the altitude- and seasonal-dependent aerosol profiles and aerosol extinction coefficients. IHAZE specifies a horizontal meteorological range and specifies the type of extinction for the boundary-layer aerosols (0 to 2 km). The relative humidity dependence of the boundary-layer aerosol extinction coefficients is based on the water vapor content of the model atmosphere selected by MODEL. ISEASN selects the seasonal dependence of the profiles for both the tropospheric (2 to 10 km) and stratospheric (10 to 30 km) aerosols. IVULCN is used to select both the profile and extinction type for the stratospheric aerosols and to determine transition profiles above the stratosphere to 100 km. VIS, the meteorological range, when specified, will supersede the default meteorological range in the boundary-layer aerosol profile set by IHAZE.

IHAZE = 0 no aerosol attenuation included in the calculation.
= 1 RURAL extinction, 23-km VIS.
= 2 RURAL extinction, 5-km VIS.
= 3 MARITIME extinction, 23-km VIS.
= 4 MARITIME extinction, 5-km VIS.
= 5 URBAN extinction, 5-km VIS.
= 6 TROPOSPHERIC extinction, 50-km VIS.
= 7 USER-DEFINED extinction, 23-km VIS. (Read into the program immediately after CARD1. Refer to the main program LOWEM in Appendix A for the input format of the coefficients).
= 8 FOG1 (Advection Fog) extinction, 0.2-km VIS.
= 9 FOG2 (Radiation Fog) extinction, 0.5-km VIS.

As noted above, IHAZE selects the type of extinction and a default meteorological range for the boundary-layer aerosol models only. If VIS is also specified on CARD1 it will override the default IHAZE value. Interpolation of the extinction coefficients based on relative humidity is performed only for the RURAL, MARITIME, URBAN, and TROPOSPHERIC coefficients used in the boundary layer (0 to 2-km altitude).

ISEASN = 0 season determined by the value of MODEL:
SPRING-SUMMER for MODEL = 0, 1, 2, 4, 6, 7
FALL-WINTER for MODEL = 3, 5
= 1 SPRING-SUMMER
= 2 FALL-WINTER

ISEASN selects the appropriate seasonal aerosol profile for both the tropospheric and stratospheric aerosols. Only the tropospheric aerosol extinction coefficients are used with the 2- to 10-km profiles.

IVULCN = 0, 1 BACKGROUND STRATOSPHERIC profile and extinction
= 2 MODERATE VOLCANIC profile and AGED VOLCANIC extinction
= 3 HIGH VOLCANIC profile and FRESH VOLCANIC extinction
= 4 HIGH VOLCANIC profile and AGED VOLCANIC extinction
= 5 MODERATE VOLCANIC profile and FRESH VOLCANIC extinction

The parameter IVULCN controls both the selection of the aerosol profile as well as the type of extinction for the stratospheric aerosols. It also selects appropriate transition profiles above the stratosphere to 100 km. Meteoric dust extinction coefficients are always used for altitudes from 30 to 100 km.

VIS = meteorological range (km) (when specified, supersedes default value set by IHAZE)

Table 2B summarizes the use of aerosol control parameters on CARD 1.

Table 2b. LOWTRAN CARD 1 Input Parameters: IHAZE, ISEASN, IVULCN, VIS

<table>
<tr><td colspan="3">CARD 1</td><td colspan="8">MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML,
IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS
FORMAT (1113, 2F10.3, 213, F10.3)</td></tr>
<tr><td colspan="3">IHAZE</td><td colspan="2">ISEASN</td><td colspan="6">IVULCN</td></tr>
<tr><td>COL 6</td><td>VIS* (KM)</td><td>EXTINCTION</td><td>COL 56</td><td>SEASON</td><td>COL 59</td><td>SEASON</td><td>PROFILE</td><td>EXTINCTION</td><td>PROFILE/ EXTINCTION</td></tr>
<tr><td>0</td><td colspan="9">← NO AEROSOLS →</td></tr>
<tr><td>1</td><td>23</td><td rowspan="2">RURAL</td><td>0</td><td>SET BY MODEL</td><td></td><td>SET BY MODEL</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3">METEORIC DUST EXTINCTION</td></tr>
<tr><td>2</td><td>5</td><td>1</td><td>SPRING-SUMMER</td><td></td><td>SPRING-SUMMER</td></tr>
<tr><td>3</td><td>23</td><td rowspan="2">MARITIME</td><td>2</td><td>FALL-WINTER</td><td></td><td>FALL-WINTER</td></tr>
<tr><td>4</td><td>5</td><td colspan="2" rowspan="6">TROPOSPHERIC PROFILE/ TROPOSPHERIC EXTINCTION</td><td>0</td><td rowspan="6"></td><td rowspan="2">BACKGROUND STRATO-SPHERIC</td><td rowspan="2">BACKGROUND STRATO-SPHERIC</td><td rowspan="2">NORMAL ATMOSPHERIC PROFILE</td></tr>
<tr><td>5</td><td>5</td><td>URBAN</td><td>1</td></tr>
<tr><td>6</td><td>50</td><td>TROPOSPHERIC</td><td>2</td><td>MODERATE VOLCANIC</td><td>AGED VOLCANIC</td><td rowspan="4">TRANSITION PROFILES -VOLCANIC TO NORMAL</td></tr>
<tr><td>7</td><td>23</td><td>USER DEFINED</td><td>3</td><td>HIGH VOLCANIC</td><td>FRESH VOLCANIC</td></tr>
<tr><td>8</td><td>0.2</td><td>FOG 1</td><td>4</td><td>HIGH VOLCANIC</td><td>AGED VOLCANIC</td></tr>
<tr><td>9</td><td>0.5</td><td>FOG 2</td><td>5</td><td>MODERATE VOLCANIC</td><td>FRESH VOLCANIC</td></tr>
<tr><td colspan="3">← 0 TO 2 KM →</td><td colspan="2">← 2 TO 10 KM →</td><td colspan="4">← 10 TO 30 KM →</td><td>← 30 TO 100 KM →</td></tr>
<tr><td colspan="10">* VIS>0, OVERRIDES DEFAULT MET. RANGE</td></tr>
</table>

In the case where MODEL = 7, the new atmosphere (model or radiosonde data) is inserted between CARDS 1 and 2 (see Section 8.3).

8.2.2 CARD 2 — H1, H2, ANGLE, RANGE, BETA

CARD 2 is used to define the geometrical path parameters for a given problem.

H1 = initial altitude (km)

H2 = final altitude (km)

It is important to emphasize here that in the radiance mode of program execution (IEMISS=1), H1, the initial altitude, always defines the position of the observer (or sensor). H1 and H2 cannot be used interchangeably as in the transmittance mode.

ANGLE = initial zenith angle (degrees) as measured from H1

RANGE = path length (km)

BETA = earth center angle subtended by H1 and H2 (degrees)

It is not necessary to specify every quantity given above; only those that adequately describe the problem according to the parameter ITYPE (as described below)

(1) Horizontal Paths (ITYPE = 1)

(a) specify H1, RANGE

(b) If non-standard meteorological data are to be used, that is, if MODEL = 0 on CARD 1, then refer to Section 8.3 for parameters and format of CARD 2.

(2) Slant Paths to Space (ITYPE = 3)

(a) specify H1, ANGLE

(b) specify H1, HMIN (for limb-viewing problem where HMIN is the required tangent height or minimum altitude of the path trajectory.

(3) Slant Paths Between Two Altitudes (ITYPE = 2)

(a) specify H1, H2, ANGLE

(b) specify H1, ANGLE, RANGE

(c) specify H1, H2, RANGE

For cases (b) and (c), the program will calculate H2 and ANGLE respectively, assuming no refraction; then proceed as for case (a). This method of defining the problem should be used when refraction effects are not important; for example, for ranges of a few tens of km at zenith angles less than 80°. It can also be used for larger angles (including 90°) provided that the path lies within one atmospheric layer.

(d) specify H1, H2, BETA. Leave ANGLE and RANGE blank in this case. This method can be used when the geometrical configuration of the source and receiver is known accurately, but the initial zenith angle is not known precisely due to atmospheric refraction effects. Beta is most frequently determined by the user from ground range information.

In the cases of 2(b) and 3(d) above, the subroutine ANGLE is called in the program to determine the appropriate input zenith angle by an iterative technique taking into account atmospheric refraction.

In the case where MODEL = 7, the new model atmosphere (or radiosonde data) is inserted between CARDS 1 and 2.

Table 3 lists the options on CARD 2 provided to the user for the different types of atmospheric paths.

Table 3. LOWTRAN CARD 2 Input Parameters: H1, H2, ANGLE, RANGE, BETA

CARD 2	H1, H2, ANGLE, RANGE, BETA FORMAT (5F10.3)				
	H1 (KM)	H2 (KM)	ANGLE (°)	RANGE (KM)	BETA (°)
ITYPE					
1	X			X	
2	X	X	X		
	X		X	X	
	X	X		X	
	X	X			X
3	X		X		
	X	X (HMIN)			
X - PARAMETER MUST BE DEFINED					

8.2.3 CARD 3 – V1, V2, DV

The spectral range over which transmittance data are required and the spectral increments at which the data are to be printed out is determined by CARD 3.

V1 = initial frequency in wavenumbers (cm^{-1})

V2 = final frequency in wavenumbers (cm^{-1}) where V2 > V1

DV = frequency increment (or step size) (cm^{-1})

(Note that $\nu = 10^4/\lambda$ where ν is the frequency in cm^{-1} and λ is the wavelength in microns, and that DV can only take values which are a multiple of 5.)

8.2.4 CARD 4 – IXY

The control parameter IXY can cause the program to recycle, so that a series of problems can be run with one submission of LOWTRAN. Five values of IXY can be used to provide the options given on the following pages.

IXY = 0 or blank card to end of program
- = 1 to select a new CARD 3 and CARD 4 only (assuming other parameters are unchanged)
- = 2 to select a new data sequence (CARDS 1, 2, 3, and 4)
- = 3 to select a new CARD 2 and CARD 4 only (assuming other parameters are unchanged)
- = 4 to select a new CARD 1 and CARD 4 only (assuming other parameters are unchanged)

Thus, if for the same model atmosphere and type of atmospheric path the reader wishes to make further transmittance calculations in different spectral intervals V1' to V2' etc. and for a different step size (DV' etc.), then IXY is set equal to 1. In this case, the card sequence is as follows and can be repeated as many times as required.

CARD 4 IXY = 1
CARD 5 V1' V2' DV'
CARD 6 IXY = 1
CARD 7 V1'' V2'' DV''
CARD 8 IXY = 0

The final IXY card should always be a blank or zero. When using the IXY = 1 option, the wavelength dependence of the refractive index is not changed (use IXY = 2 option if this is required).

To make successive transmittance computations where just the geographical model atmosphere is changed and/or with or without aerosol attenuation, set IXY = 4 and construct a data card sequence along the same lines as given above. This sequence of recycling can be repeated successively.

When a series of problems is to be executed (with one submission of LOWTRAN) involving the standard atmospheric models (MODEL = 1 to 6) as well as cases involving MODEL = 0 and MODEL = 7, then the order in which the data are set up becomes very important. Note the following sequence.

1. Run all problems using MODEL = 1 through 6 first.
2. Secondly, run all problems involving the use of MODEL = 0.
3. Run all problems involving the use of MODEL = 7 last. The reason for running MODEL = 7 cases last is that when a new atmospheric model is read in,

the altitudes may not correspond with those given in the standard models and the program will erase them. Similarly, if a MODEL = 0 case is run following a MODEL = 7 case, the first level of MODEL 7 is erased.

Table 4 summarizes the user-control parameters on CARD 3 and CARD 4.

Table 4. LOWTRAN CARD 3 and CARD 4 Input Parameters: V1, V2, DV, IXY

CARD 3	V1, V2, DV FORMAT (3F10.3)			
	V1 (CM-1)	V2 (CM-1)	DV (CM-1)	DV VALUES MULTIPLE OF 5 CM-1
CARD 4	IXY FORMAT (I3)			

COL 3	IXY
0	END OF PROGRAM.
1	READ NEW CARDS 3 AND 4.
2	READ NEW CARDS 1, 2, 3, AND 4.
3	READ NEW CARDS 2 AND 4.
4	READ NEW CARDS 1 AND 4.

8.3 Non-Standard Conditions

Three options are available if atmospheric transmittance calculations are required for non-standard conditions. Here non-standard refers to conditions other than those specified by the six model atmospheres provided by LOWTRAN, which are selected by the parameter MODEL on CARD 1. The three options enable the user to insert:

(1) His own model atmosphere(s) in place of any (or all) of the six standard models, provided that the data are in exactly the same format and are specified at the same altitudes as in the DATA statements in the LOWTRAN code (Subroutine MDTA). In this case the appropriate print statements in LOWTRAN (that identify the atmospheric model used) must be changed correspondingly.

(2) An additional atmospheric model (MODEL 7), which can be in the form of radiosonde data. The data need not be specified at the same altitudes as in the standard models.

(3) Meteorological conditions for a given horizontal path calculation (MODEL = 0 case).

The first of these options requires the most effort and needs no further discussion here, other than a reference to Appendix A for a summary of the standard model atmosphere parameters, units, and formats.

8.3.1 ADDITIONAL ATMOSPHERIC MODEL (MODEL = 7)

New model atmospheres can be inserted between CARDS 1 and 2 provided the parameters MODEL and IM are set equal to 7 and 1 respectively on CARD 1. The number of atmospheric levels to be inserted (ML) must also be specified on CARD 1. New altitude-dependent aerosol control options have been added to the MODEL = 7 cards to provide more flexibility to the user in modeling aerosol extinction.

The appropriate meteorological parameters and format for the atmospheric data are given below

Z, P, T, DP, RH, WH, WO, AHAZE, VIS1, IHA1, ISEA1, IVUL1
FORMAT (3F10.3, 2F5.1, 3E10.3, F7.3, 3I1)

Z	= altitude (km)
P	= pressure (mb)
T	= ambient temperature (^{o}C)
DP	= dew-point temperature (^{o}C)
RH	= relative humidity (%)
WH	= water vapor density (gm m^{-3})
WO	= ozone density (gm m^{-3})
AHAZE	= aerosol number density (normalized by the user to the required meteorological range using the LOWTRAN extinction coefficients)
VIS1	= meteorological range (km) for the altitude, Z
IHA1	= aerosol extinction and meteorological range control for the altitude, Z
ISEA1	= aerosol season control for the altitude, Z
IVUL1	= aerosol profile and extinction control for the altitude, Z

Note that it is only necessary to specify those quantities underlined with a full line and one of the quantities underlined with the dashed line.

If the ozone density (WO) is not known then a value can be obtained from one of the standard atmospheric models (for the appropriate latitude and season) by using the parameter M3 on CARD 1.

Also note that for M1 > 0 on CARD 1, both pressure and temperature are now interpolated from the model atmosphere (MODEL=M1) for the altitude Z.

For the modeling of the aerosol profiles and extinction coefficients, if AHAZE, VIS1, ISEA1 and IVUL1 are left blank on the MODEL 7 input card, then the aerosol control parameters, IHAZE, ISEASN, IVULCN and VIS on CARD 1 will control the modeling of the altitude-dependent aerosol parameters as described in Section 8.2. LOWTRAN will use the aerosol models contained in the program and interpolate the profiles to the same altitudes as the radiosonde (or new model atmosphere) data.

The additional aerosol options on the MODEL 7 card have been added primarily to provide more user flexibility in modeling altitude-dependent aerosols such as low ground fogs where finer altitude resolution is required to specify the aerosol profile. These options are categorized as follows:

(a) AHAZE > 0, VIS1 = IHA1 = ISEA1 = IVUL1 = 0

For this case, the program will use the value of AHAZE at the altitude, Z, to define the aerosol profile. The parameters on CARD 1 will be used only to select the type of aerosol extinction coefficients to be used in the (0-2 km), (2-10 km), (10-30 km), and (30-100 km) altitude regions as in the MODEL=1 to six cases. VIS on CARD 1 is not used. The user must scale the AHAZE values to the proper sea-level meteorological range.

(b) AHAZE > 0, either IHA1 > 0 or IVUL1 > 0, ISEA1 = 0

where IHA1 = 1 to 9 with the same extinction coefficient options as IHAZE in Section 8.2, and IVUL1 = 1 to 5 with the same extinction coefficient options as IVULCN in Section 8.2. When IHA1 is defined, it will select the type of extinction coefficient to be used with AHAZE at the altitude, Z, and correspondingly when IVUL1 is defined. Only four different altitude regions are allowed for the aerosols in the program. The boundary altitudes are determined from the altitude, Z, on the MODEL 7 card when either IHA1 or IVUL1 changes value. These boundaries do not necessarily have to correspond to the default values in the standard models.

(c) AHAZE = 0, either one or all of the parameters VIS1, IHA1, ISEA1 and IVUL1 defined

where ISEA1 = 1 or 2 with the same seasonal profile options as ISEASN in Section 8.2. The aerosol profiles and extinction coefficients will be determined by the values of these parameters at each altitude Z. Again, as in (b) only four altitude regions for the aerosols are allowed in the program, with the boundaries of the regions determined by the altitude Z when the control parameters change. Note also that IHA1 takes precedence over IVUL1 in the selection of the type of extinction coefficients. Examples of the use of these aerosol options are shown in Section 9.

Although data for cloud extinction is not provided in the LOWTRAN code, these additional aerosol options do allow for user cloud modeling in the atmosphere with the aerosol control parameters on the MODEL 7 card.

Note that IHAZE must be defined to some initial value greater than zero to calculate aerosol extinction and that at least two altitudes are needed to define an aerosol altitude region.

8.3.2 HORIZONTAL PATHS (MODEL = 0)

If meteorological data are to be used for horizontal path atmospheric transmittance calculations, then set MODEL = 0 on CARD 1. The following parameters can then be specified on CARD 2.

CARD 2 H1, P, T, DP, RH, WH, WO, RANGE (FORMAT 3F10.3, 2F5.1, 2E10.3, F10.3) where the above parameters refer to altitude (km), pressure (mb) ambient temperature (^{o}C), dew-point temperature (^{o}C), relative humidity (%), water vapor density (gm m^{-3}), ozone density (gm m^{-3}), and path length (km) respectively.

The format for the above card is similar to that for inputting radiosonde data (MODEL = 7). Again, it is only necessary to specify the quantities underlined with the solid line and one of the quantities underlined with the dashed line. The ozone density WO can be specified using the parameter M3 on CARD 1 if measurements are not available. In the latter case, a value will be calculated at altitude H1 based on the appropriate model atmosphere selected by M3.

The aerosol control parameters for the MODEL = 0 cases are on CARD1 as described in Section 8.2.

9. EXAMPLES OF PROGRAM OUTPUT

Seven cases, representative of different types of atmospheric slant paths, mode of program execution, and atmospheric and aerosol models are presented in this section. The input cards to the program for these cases are listed in Table 5. A description of the program output for each of the cases, calculated from LOWTRAN, follows.

Case 1. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a slant path from 20 km to space at a zenith angle of 90^{o}, for the U.S. Standard model atmosphere, and a 23-km meteorological range for the rural aerosol model.

The output for Case 1 is given in Table 6. A message indicating the mode of execution of the program is printed as the first line of output. For this problem, execution will be in the transmittance mode.

The parameters defining the atmospheric slant path, model atmosphere, aerosol model, and wavenumber range are next printed out.

Table 5. Input Cards for the Seven Test Cases

CASE 1	CARD 1	6 1 3							
	CARD 2	20.		90.					
	CARD 3	900.	1145.	5.					
	CARD 4	2							
CASE 2	CARD 1	6 1 3			1				
	CARD 2	20.		90.					
	CARD 3	900.	1145.	5.					
	CARD 4	2							
CASE 3	CARD 1	6 1 1							
	CARD 2	0.	0.	0.	1.	0.			
	CARD 3	900.	1145.	5.					
	CARD 4	2							
CASE 4	CARD 1	2 3 2							
	CARD 2	12.0	0.	180.					
	CARD 3	900.	1145.	5.					
	CARD 4	2							
CASE 5	CARD 1	0 1 1 0 0 1 0 0 3							
	MODEL=0	0.	1000.	10.	40.		10.		
	CARD 3	900.	1146.	5.					
	CARD 4	2							
CASE 6	CARD 1	7 3 2 0 0 1 0 0 2 21							
	MODEL=7	0.	1015.	24.4	21.4				
	MODEL=7	0.136	1000.	22.	19.4				
	MODEL=7	0.550	950.	17.8	16.1				
	MODEL=7	1.08	902.	14.6	11.9				
	MODEL=7	1.526	850.	12.8	5.8				
	MODEL=7	1.65	832.	12.8	-6.2				
	MODEL=7	2.27	775.	11.8	-18.2				
	MODEL=7	3.14	700.	7.2	-20.8				
	MODEL=7	5.92	500.	-10.1	-28.1				
	MODEL=7	5.99[illegible]	488.	-11.5	-27.5				
	MODEL=7	7.51	400.	-19.5	-31.5				
	MODEL=7	8.72	335.	-28.5	-41.5				
	MODEL=7	9.18	318.	-32.7	-39.7				
	MODEL=7	9.59	300.	-35.3	-43.3				
	MODEL=7	9.72	294.	-34.7	-42.7				
	MODEL=7	10.[illegible]	281.	-38.7	-45.7				
	MODEL=7	11.83	250.	-44.7	-50.				
	MODEL=7	12.[illegible]	200.	-57.1	-50.				
	MODEL=7	13.6	161.	-69.5	-50.				
	MODEL=7	14.[illegible]	150.	-71.1	-50.				
	MODEL=7	16.45	100.	-70.9	-50.				
	CARD 2	0.01	9.55	35.5					
	CARD 3	900.	1145.	5.					
	CARD 4	2							
CASE 7	CARD 1	7 9 2 0 0 1 6 6 6 1[illegible]							
	MODEL=7	.0							
	MODEL=7	.2							
	MODEL=7	.201						23.	1
	MODEL=7	1.0						23.	1
	MODEL=7	2.0						23.	1
	MODEL=7	2.01							
	MODEL=7	5.							
	MODEL=7	10.							
	MODEL=7	11.							
	MODEL=7	30.							
	MODEL=7	35.							
	MODEL=7	70.							
	CARD 2	0.	10.						
	CARD 3	900.	1145.	5.					
	CARD 4	[illegible]							

Table 6. Program Output for Case 1

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
6  1  3  6  0  0  0  0  0  0  0      0.000       0.000  0  0       0.000
             20.000       0.000     90.000       0.000       0.000
 900.000  1145.000       5.000
```

SLANT PATH TO SPACE FROM ALTITUDE H1 = 20.000 KM, ZENITH ANGLE = 90.000 DEGREES

HAZE MODEL = 23.0 KM VISUAL RANGE AT SEA LEVEL

MODEL ATMOSPHERE 6 = 1962 US STANDARD

HAZE MODEL 1 = RURAL VIS= 23.0KM

SEASON = SPRIG SUMM

VERTICAL PROFILE AEROSOL MODEL = STRAT BKGR

FREQUENCY RANGE V1= 900.0 CM-1 TO V2= 1145.0 CM-1 FOR DV = 5.0 CM-1 (8.73 - 11.11 MICRONS)

HORIZONTAL PROFILES

ID	ALT	P	T	H2O	CO2+	O3	N2	H2O(10M)	MOLS	(N-1)	O3(UV)
1	0.00	1013.000	288.100	5.761E-01	9.294E-01	2.493E-03	7.385E-01	6.574E-03	9.481E-01	2.595E-04	2.520E-03
2	1.00	898.600	281.600	7.719E-01	7.776E-01	2.387E-03	6.014E-01	3.832E-03	8.604E-01	2.353E-04	2.520E-03
3	2.00	795.000	275.100	2.324E-01	5.490E-01	2.284E-03	4.875E-01	2.127E-03	7.792E-01	2.129E-04	2.520E-03
4	3.00	701.200	268.700	1.302E-01	5.373E-01	2.021E-03	3.929E-01	9.547E-04	7.037E-01	1.921E-04	2.333E-03
5	4.00	616.600	262.200	7.167E-02	4.437E-01	1.775E-03	3.152E-01	4.504E-04	6.341E-01	1.729E-04	2.147E-03
6	5.00	540.500	255.700	3.745E-02	3.648E-01	1.692E-03	2.515E-01	1.927E-04	5.700E-01	1.552E-04	2.147E-03
7	6.00	472.200	249.200	1.992E-02	2.983E-01	1.576E-03	1.995E-01	8.679E-05	5.109E-01	1.390E-04	2.100E-03
8	7.00	411.100	242.700	9.636E-03	2.428E-01	1.632E-03	1.573E-01	3.559E-05	4.567E-01	1.241E-04	2.287E-03
9	8.00	356.500	236.200	5.105E-03	1.964E-01	1.645E-03	1.232E-01	1.567E-05	4.070E-01	1.104E-04	2.427E-03
10	9.00	308.000	229.700	1.703E-03	1.580E-01	2.131E-03	9.590E-02	4.079E-06	3.616E-01	9.792E-05	3.313E-03
11	10.00	265.000	223.200	5.897E-04	1.263E-01	2.556E-03	7.412E-02	1.181E-06	3.201E-01	8.654E-05	4.200E-03
12	11.00	227.000	216.800	2.362E-04	1.003E-01	3.493E-03	5.681E-02	4.288E-07	2.823E-01	7.525E-05	6.067E-03
13	12.00	194.000	216.600	9.779E-05	7.627E-02	4.038E-03	4.155E-02	1.543E-07	2.415E-01	6.434E-05	7.467E-03
14	13.00	165.800	216.600	3.919E-05	5.794E-02	4.029E-03	3.035E-02	6.189E-08	2.064E-01	5.499E-05	7.933E-03
15	14.00	141.700	216.600	1.588E-05	4.402E-02	4.229E-03	2.217E-02	2.415E-08	1.764E-01	4.699E-05	6.667E-03
16	15.00	121.100	216.600	1.182E-05	3.344E-02	4.389E-03	1.619E-02	1.769E-08	1.508E-01	4.016E-05	9.800E-03
17	16.00	103.500	216.650	8.591E-06	2.540E-02	4.711E-03	1.183E-02	1.281E-08	1.288E-01	3.433E-05	1.120E-02
18	17.00	88.500	216.600	6.435E-06	1.931E-02	5.162E-03	8.647E-03	9.334E-09	1.102E-01	2.935E-05	1.307E-02
19	18.00	75.650	216.600	4.728E-06	1.468E-02	5.541E-03	6.316E-03	6.749E-09	9.418E-02	2.509E-05	1.493E-02
20	19.00	64.670	216.600	4.106E-06	1.115E-02	5.592E-03	4.617E-03	5.796E-09	8.051E-02	2.145E-05	1.633E-02
21	20.00	55.290	216.600	3.565E-06	8.479E-03	5.804E-03	3.375E-03	4.961E-09	6.883E-02	1.830E-05	1.773E-02
22	21.00	47.290	217.600	3.372E-06	6.409E-03	5.448E-03	2.452E-03	4.686E-09	5.860E-02	1.559E-05	1.773E-02
23	22.00	40.470	218.600	3.169E-06	4.850E-03	5.248E-03	1.783E-03	4.387E-09	4.992E-02	1.329E-05	1.820E-02
24	23.00	34.670	219.600	3.016E-06	3.676E-03	4.803E-03	1.380E-03	4.171E-09	4.257E-02	1.133E-05	1.773E-02
25	24.00	29.720	220.600	2.804E-06	2.790E-03	4.274E-03	9.488E-04	3.876E-09	3.633E-02	9.673E-06	1.680E-02
26	25.00	25.490	221.600	2.637E-06	2.119E-03	3.793E-03	6.932E-04	3.660E-09	3.102E-02	6.502E-06	1.587E-02
27	30.00	11.970	226.500	7.514E-07	5.479E-04	1.642E-03	1.475E-04	9.944E-10	1.425E-02	2.988E-06	9.333E-03
28	35.00	5.746	236.500	1.624E-07	1.429E-04	6.674E-04	3.195E-05	1.943E-10	6.551E-03	1.380E-06	5.133E-03
29	40.00	2.871	253.400	3.531E-08	3.860E-05	2.222E-04	7.192E-06	3.942E-11	3.055E-03	6.574E-07	2.287E-03
30	45.00	1.491	264.200	9.178E-09	1.158E-05	5.882E-05	1.822E-06	9.676E-12	1.522E-03	3.326E-07	7.933E-04
31	50.00	.798	270.600	1.939E-09	3.751E-06	1.072E-05	5.032E-07	1.922E-12	7.950E-04	1.239E-07	1.867E-04
32	70.00	.055	219.700	2.406E-12	4.662E-08	8.259E-08	3.293E-09	1.653E-15	6.775E-05	9.787E-09	4.013E-06
33	100.00	.000	210.000	1.502E-16	5.422E-12	5.181E-12	1.046E-13	6.054E-20	3.862E-07	5.548E-11	2.047E-09
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

Table 6. Program Output for Case 1 (Cont.)

HORIZONTAL PROFILES

ID	ALT	P	T	H2O(4M)	HNO3	AER1	AER2	AER3	AER4	(AER1*RH)	RH!
1	0.00	1013.000	288.100	8.479E-02	0.	1.580E-01	0.	0.	0.	7.226E+00	4.575E+01
2	1.00	898.600	281.600	5.897E-02	0.	9.910E-02	0.	0.	0.	4.862E+00	4.906E+01
3	2.00	795.000	275.100	3.993E-02	0.	6.210E-02	0.	0.	0.	3.238E+00	5.214E+01
4	3.00	701.200	268.700	2.432E-02	0.	0.	3.460E-02	0.	0.	0.	0.
5	4.00	616.600	262.200	1.459E-02	0.	0.	1.850E-02	0.	0.	0.	0.
6	5.00	540.500	255.700	8.494E-03	0.	0.	9.310E-03	0.	0.	0.	0.
7	6.00	472.200	249.200	5.779E-03	0.	0.	7.710E-03	0.	0.	0.	0.
8	7.00	411.100	242.700	2.796E-03	0.	0.	6.230E-03	0.	0.	0.	0.
9	8.00	356.500	236.200	1.612E-03	4.070E-55	0.	3.370E-03	0.	0.	0.	0.
10	9.00	308.000	229.700	6.266E-04	3.616E-06	0.	1.820E-03	0.	0.	0.	0.
11	10.00	265.000	223.200	2.502E-04	1.056E-05	0.	0.	1.140E-03	0.	0.	0.
12	11.00	227.000	216.800	1.167E-04	2.259E-05	0.	0.	7.990E-04	0.	0.	0.
13	12.00	194.000	216.600	4.529E-05	2.898E-05	0.	0.	6.410E-04	0.	0.	0.
14	13.00	165.800	216.600	1.681E-05	2.890E-05	0.	0.	5.170E-04	0.	0.	0.
15	14.00	141.700	216.600	7.502E-06	2.822E-05	0.	0.	4.420E-04	0.	0.	0.
16	15.00	121.100	216.600	5.496E-06	2.714E-05	0.	0.	3.950E-04	0.	0.	0.
17	16.00	103.500	216.600	3.979E-06	2.448E-05	0.	0.	3.820E-04	0.	0.	0.
18	17.00	88.500	216.600	2.301E-06	2.203E-05	0.	0.	4.290E-04	0.	0.	0.
19	18.00	75.650	216.600	2.199E-06	1.978E-05	0.	0.	5.200E-04	0.	0.	0.
20	19.00	64.670	216.600	1.794E-06	1.852E-05	0.	0.	5.810E-04	0.	0.	0.
21	20.00	55.290	216.600	1.577E-06	2.065E-05	0.	0.	5.890E-04	0.	0.	0.
22	21.00	47.290	217.600	1.391E-06	2.168E-05	0.	0.	5.320E-04	0.	0.	0.
23	22.00	40.470	218.600	1.253E-06	2.097E-05	0.	0.	4.200E-04	0.	0.	0.
24	23.00	34.670	219.600	1.144E-06	2.214E-05	0.	0.	3.100E-04	0.	0.	0.
25	24.00	29.720	220.600	1.221E-06	2.180E-05	0.	0.	1.380E-04	0.	0.	0.
26	25.00	25.490	221.600	9.214E-07	1.179E-05	0.	0.	1.310E-04	0.	0.	0.
27	30.00	11.970	226.500	2.184E-07	3.705E-06	0.	0.	3.320E-05	0.	0.	0.
28	35.00	5.746	236.500	7.431E-08	1.441E-07	0.	0.	0.	1.540E-05	0.	0.
29	40.00	2.871	253.400	4.306E-19	3.055E-57	0.	0.	0.	7.990E-06	0.	0.
30	45.00	1.491	264.200	3.787E-10	0.	0.	0.	0.	4.010E-06	0.	0.
31	50.00	.798	270.600	1.749E-10	0.	0.	0.	0.	2.100E-06	0.	0.
32	70.00	.055	219.700	4.779E-13	0.	0.	0.	0.	1.600E-07	0.	0.
33	100.00	.000	210.000	2.706E-17	0.	0.	0.	0.	9.310E-10	0.	0.
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

FROM POINT \ HEIGHT= 20.0000 KM,N= 21,NP= 1,REF. INDEX ABOVE & BELOW X= .1930E-04 .2145E-04,IP= 1
EQUIV. ABSORBED AMOUNTS PER KM AT X= .357E-05 .848E-02 .530E-02 .332E-02 .498E-08 .688E-01 0. .17 E-01

TX(12-14)= 0. .589E-03 0.1

Table 6. Program Output for Case 1 (Cont.)

VERTICAL PROFILE

ID	ALT	H2O	CO2+ / H2O(4M)	O3 / HNO3	N2 / AER2	H2O(10M) / AER3	HOLS / AER4	AER1	O3(UV)	PSI	PHI	BETA	THETA	RANGE / DRANGE
21	20.000	3.921E-04	6.362E-01	6.759E-01	3.266E-01	5.463E-07	7.188E+00	0.	2.005E+00	-.0000	91.0135	1.1135	[illegible]	113.1
	21.000		1.552E-04	2.347E-03	0.	6.155E-02	0.							113.06
22	21.000	9.452E-04	1.100E+00	8.879E-01	4.256E-01	7.600E-07	9.749E+00	0.	2.852E+00	.0088	[illegible].4270	1.4358	68.9954	160.2
	22.000		2.274E-04	3.398E-03	0.	8.321E-02	0.							47.13
23	22.000	6.581E-04	1.253E+00	1.070E+00	4.809E-01	9.148E-07	1.141E+01	0.	3.502E+00	.0141	91.7458	1.7599	68.5783	196.4
	23.000		2.707E-04	4.177E-03	0.	9.612E-02	0.							36.18
24	23.000	7.465E-04	1.351E+00	1.208E+00	5.159E-01	1.038E-06	1.261E+01	0.	4.028E+00	.0178	92.0153	2.0331	88.2579	226.9
	24.000		3.037E-04	4.947E-03	0.	1.036E-01	0.							30.50
25	24.000	8.199E-04	1.417E+00	1.316E+00	5.368E-01	1.139E-06	1.351E+01	0.	4.467E+00	.0205	92.2531	2.2736	87.9875	253.7
	25.000		3.298E-04	5.285E-03	0.	1.080E-01	0.							26.87
26	25.000	9.790E-04	1.539E+00	1.587E+00	5.740E-01	1.356E-06	1.579E+01	0.	5.764E+00	.0251	93.1309	3.2161	87.7519	359.1
	30.000		3.812E-04	6.020E-03	0.	1.155E-01	0.							105.37
27	30.000	1.019E-03	1.563E+00	1.674E+00	5.801E-01	1.394E-06	1.659E+01	0.	6.332E+00	.0288	93.9088	3.9375	86.8127	439.9
	35.000		3.893E-04	6.109E-03	0.	1.155E-01	0.							80.79
28	35.000	1.016E-03	1.569E+00	1.702E+00	5.813E-01	1.401E-06	1.690E+01	0.	6.572E+00	.0301	94.5146	4.5447	86.0925	503.0
	40.000		3.903E-04	6.109E-03	0.	1.155E-01	7.963E-04							6[illegible].09
29	40.000	1.017E-03	1.570E+00	1.709E+00	5.815E-01	1.402E-06	1.703E+01	0.	6.656E+00	.0306	95.0481	5.0767	85.4660	568.0
	45.000		3.904E-04	6.109E-03	0.	1.155E-01	1.143E-03							59.99
30	45.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.709E+01	0.	6.679E+00	.0306	95.5300	5.5608	84.9521	622.2
	50.000		3.905E-04	6.109E-03	0.	1.155E-01	1.303E-03							54.24
31	50.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.714E+01	0.	6.688E+00	.0310	97.1353	7.1663	84.4701	803.5
	70.000		3.905E-04	6.109E-03	0.	1.155E-01	1.439E-03							181.31
32	70.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	.0310	99.0120	9.0430	82.8647	1017.1
	100.000		3.905E-04	6.109E-03	0.	1.155E-01	1.446E-03							213.58
33	100.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E 00	.0310	176.5553	86.5863	80.9880	*******
	********		3.905E-04	6.109E-03	0.	1.155E-01	1.446E-03							*******
34	*********	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	.0309	176.5553	86.5563	3.4447	*******
	********		3.905E-04	6.109E-03	0.	1.155E-01	1.446E-03							0.00

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AER1	OZONE(U-V) ATM CM / NITRIC ACID
W(1-9)=	.102E-02	.157E+01	.171E+01	.582E+00	.140E-05 .390E-03	.171E+02	0.	.665E+01 .611E-02

	AER2	AER3	AER4	R.H. MEAN
W(12-15)=	0.	1.155E-01	1.446E-03	0.1

Table 6. Program Output for Case 1 (Cont.)

ICH 1 6 10 15
EXTINCTION AND ABSORPTION COEFFICIENTS

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION	NITRIC ACID TRANS
900	11.1111	.9315	.9999	1.0000	1.0000	1.0000	1.0000	1.0000	.9936	.0063	.1705	.9380
905	11.0497	.9477	.9998	.9991	1.0000	1.0000	1.0000	1.0000	.9933	.0066	.4316	.9552
910	10.9890	.9553	.9998	.9988	1.0000	1.0000	1.0000	1.0000	.9931	.0068	.6564	.9632
915	10.9290	.9617	.9998	.9977	.9999	1.0000	1.0000	1.0000	.9933	.0066	.8476	.9705
920	10.8696	.9726	.9998	.9964	.9999	1.0000	1.0000	1.0000	.9936	.0063	.9845	.9826
925	10.8108	.9878	.9999	.9943	.9997	1.0000	1.0000	1.0000	.9939	.0060	1.0454	1.0000
930	10.7527	.9851	.9999	.9916	.9993	1.0000	1.0000	1.0000	.9942	.0057	1.1196	1.0000
935	10.6952	.9812	.9999	.9882	.9985	1.0000	1.0000	1.0000	.9945	.0054	1.2139	1.0000
940	10.6383	.9773	.9999	.9855	.9970	1.0000	1.0000	1.0000	.9947	.0052	1.3274	1.0000
945	10.5820	.9728	.9999	.9836	.9942	1.0000	1.0000	1.0000	.9949	.0050	1.4632	1.0000
950	10.5263	.9352	.9999	.9827	.9465	1.0000	1.0000	1.0000	.9948	.0051	1.8371	1.0000
955	10.4712	.8745	.9998	.9831	.8944	1.0000	1.0000	1.0000	.9947	.0052	2.4646	1.0000
960	10.4167	.8346	.9998	.9829	.8538	1.0000	1.0000	1.0000	.9946	.0053	3.2917	1.0000
965	10.3627	.7784	.9993	.9827	.7966	1.0000	1.0000	1.0000	.9945	.0054	4.3996	1.0000
970	10.3093	.7066	.9998	.9808	.7246	1.0000	1.0000	1.0000	.9944	.0055	5.8667	1.0000
975	10.2564	.6347	.9998	.9803	.6539	1.0000	1.0000	1.0000	.9943	.0055	7.6934	1.0000
980	10.2041	.5111	.9999	.9831	.5229	1.0000	1.0000	1.0000	.9943	.0056	10.1381	1.0000
985	10.1523	.3931	.9999	.9884	.4001	1.0000	1.0000	1.0000	.9942	.0057	13.1724	1.0000
990	10.1010	.2776	.9999	.9938	.2812	1.0000	1.0000	1.0000	.9941	.0058	16.7636	1.0000
995	10.0503	.2273	.9999	.9974	.2290	1.0000	1.0000	1.0000	.9940	.0059	20.6455	1.0000
1000	10.0000	.1747	.9998	.9989	.1760	1.0000	1.0000	1.0000	.9939	.0060	24.7756	1.0000
1005	9.9502	.1402	.9998	.9993	.1413	1.0000	1.0000	1.0000	.9936	.0063	29.0738	1.0000
1010	9.9010	.1163	.9996	.9992	.1173	1.0000	1.0000	1.0000	.9934	.0065	33.4921	1.0000
1015	9.8522	.0952	.9997	.9985	.0960	1.0000	1.0000	1.0000	.9931	.0068	38.0161	1.0000
1020	9.8039	.0849	.9998	.9972	.0848	1.0000	1.0000	1.0000	.9929	.0071	42.5963	1.0000
1025	9.7561	.0806	.9997	.9949	.0816	1.0000	1.0000	1.0000	.9926	.0073	47.1933	1.0000
1030	9.7087	.0774	.9998	.9929	.0786	1.0000	1.0000	1.0000	.9924	.0075	51.8461	1.0000
1035	9.6618	.0560	.9998	.9684	.0571	1.0000	1.0000	1.0000	.9921	.0078	56.5262	1.0000
1040	9.6154	.0632	.9998	.9848	.0645	1.0000	1.0000	1.0000	.9919	.0080	61.2112	1.0000
1045	9.5694	.1152	.9998	.9808	.1195	1.0000	1.0000	1.0000	.9916	.0083	65.6300	1.0000
1050	9.5238	.0681	.9998	.9794	.0702	1.0000	1.0000	1.0000	.9914	.0085	70.2695	1.0000
1055	9.4787	.0597	.9998	.9774	.0617	1.0000	1.0000	1.0000	.9911	.0087	74.9906	1.0000
1060	9.4340	.0720	.9997	.9770	.0744	1.0000	1.0000	1.0000	.9909	.0090	79.6368	1.0000
1065	9.3897	.0944	.9997	.9758	.0976	1.0000	1.0000	1.0000	.9907	.0092	84.1590	1.0000
1070	9.3458	.1607	.9997	.9731	.1668	1.0000	1.0000	1.0000	.9904	.0094	88.3556	1.0000
1075	9.3023	.5035	.9997	.9727	.5229	1.0000	1.0000	1.0000	.9902	.0097	90.6380	1.0000
1080	9.2593	.6284	.9995	.9754	.6509	1.0000	1.0000	1.0000	.9900	.0099	92.6959	1.0000
1085	9.2166	.6450	.9998	.9822	.6637	1.0000	1.0000	1.0000	.9898	.0101	94.4706	1.0000
1090	9.1743	.6571	.9998	.9772	.6727	1.0000	1.0000	1.0000	.9896	.0103	96.1853	1.0000
1095	9.1324	.6615	.9997	.9941	.6727	1.0000	1.0000	1.0000	.9895	.0104	97.8775	1.0000
1100	9.0909	.6680	.9996	.9973	.6773	1.0000	1.0000	1.0000	.9894	.0105	99.5376	1.0000
1105	9.0498	.6645	.9995	.9992	.6727	1.0000	1.0000	1.0000	.9893	.0106	101.2144	1.0000
1110	9.0090	.6558	.9994	.9996	.6637	1.0000	1.0000	1.0000	.9891	.0107	102.9352	1.0000
1115	8.9686	.6472	.9995	.9998	.6551	1.0000	1.0000	1.0000	.9887	.0112	104.6991	1.0000
1120	8.9286	.6426	.9996	.9995	.6509	1.0000	1.0000	1.0000	.9882	.0117	106.4855	1.0000
1125	8.8889	.6379	.9997	.9989	.6467	1.0000	1.0000	1.0000	.9877	.0122	108.2966	1.0000
1130	8.8496	.6411	.9997	.9980	.6509	1.0000	1.0000	1.0000	.9872	.0127	110.0912	1.0000
1135	8.8106	.6608	.9996	.9960	.6727	1.0000	1.0000	1.0000	.9866	.0132	111.7871	1.0000
1140	8.7719	.7009	.9996	.9922	.7166	1.0000	1.0000	1.0000	.9861	.0137	113.2629	1.0000
1145	8.7336	.7410	.9996	.9872	.7519	1.0000	1.0000	1.0000	.9856	.0142	113.9303	1.0000

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 113.93AVERAGE TRANSMITTANCE = .5350
2

Following the heading HORIZONTAL PROFILES are two pages of output, each of 12 columns. On the first page, the first four columns list a running integer associated with each level (level indicator), the level altitude in km, the level pressure (mb), and the level temperature (^{O}K). The next six columns give the equivalent absorber amounts per km for the following absorbing species: water vapor, uniformly mixed gases, ozone, nitrogen continuum, water vapor continuum (10 μm), and molecular scattering. The last two columns give the mean refractive index modulus (n - 1) from that level to the level above, and the equivalent absorber amount per km for the UV ozone.

On the second page, the first four columns, listing the level indicator, altitude, pressure, and temperature are repeated. The next two columns give the equivalent absorber amount per km for the water vapor continuum (4 μm) and for nitric acid. The next four columns give the aerosol amounts per km for the four altitude regions provided for in the program. The last two columns list the product of the aerosol density times the percent relative humidity and the percent relative humidity for the boundary-layer region.

Following the horizontal profiles, level information at H1 calculated in subroutine POINT is printed.

A heading VERTICAL PROFILES is then printed followed by two lines of output per atmospheric layer. The first column is an integer level indicator. The second column gives the altitudes of the levels traversed by the atmospheric slant path. The next eight columns give the integrated equivalent absorber amounts from the initial altitude to the level above (with the species identified as in the header). The next four columns are labelled PSI, PHI, BETA, and THETA, and correspond to the angles ψ, ϕ, β, and θ described in Section 4. Columns PSI and BETA give the accumulated values of ψ and β to the level above. Columns THETA and PHI give the local zenith angle corresponding to that level and the angle of arrival at the level above, respectively. In the last column, the accumulated slant range, RANGE, is printed, and below it the differential slant range of the levels traversed.

The total equivalent absorber amounts along the atmospheric path are then summarized in their appropriate units.

Control parameters for the altitude-dependent aerosol extinction and absorption coefficients are then printed from Subroutine EXABIN.

A transmittance table, containing 13 columns, now follows. The first three columns give the frequency (cm^{-1}) wavelength (μm), and total transmittance. The next seven columns show the individual transmittance due to water vapor, uniformly mixed gases, ozone, nitrogen (4 μm) continuum, total water vapor continuum, molecular scattering, and total aerosol extinction. The next two columns give absorption due to aerosols and the cumulative integrated absorption. The latter

quantity can be used to determine the average transmittance over any given spectral interval within the spectral range covered by the calculation. The last column gives the transmittance of nitric acid. Finally, the total integrated absorption from V1 to V2 is printed out (units are cm^{-1}) together with the average transmittance over the band.

Case 2. Calculate the radiance at H1 for the same conditions as in Case 1. The output of the program, shown in Table 7, is identical to that of Case 1 up to and including the printing of the aerosol control parameters.

Two parameters, J1 and J2, are then printed out. These parameters control the loading of the cumulative absorber amounts into the matrix, WPATH.

A heading CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH is then printed followed by 16 columns. The first column gives an integer associated with the layer traversal by the atmospheric slant path. The following 10 columns give the cumulative absorber amounts for the following species: water vapor, uniformly mixed gases, ozone, nitrogen continuum, water vapor continuum (10 μm), molecular scattering, aerosol extinction (boundary layer), UV ozone, water vapor continuum (4 μm) and nitric acid. The next column is the average temperature of the layer.

Below this output, the layer ID is repeated and the other three altitude-dependent, cumulative aerosol absorber amounts are printed.

A radiance table, containing six columns, now follows. The first two columns give the frequency (cm^{-1}) and the wavelength (μm). The next two columns give the radiance in units of W/cm^2-ster-cm^{-1} and W/cm^2-ster-μm. The next column gives the cumulative integrated radiance (W/cm^2-ster). The last column is the total transmittance.

Finally, the maximum and minimum radiances and their frequencies, the integrated absorption, the average transmittance, and the total integrated radiance are printed.

Case 3. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a 1-km horizontal path at sea level, using the U.S. Standard atmosphere and the rural, 23-km meteorological range, aerosol model.

The output for Case 3, shown in Table 8, with the exception of the omission of the vertical profiles, is similar to that described for Case 1.

Case 4. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1}, for a slant path from 12 km to ground (0 km) at a zenith angle of 180°, using the midlatitude summer model atmosphere and a maritime, 23 km meteorological range aerosol model.

The output for this case, shown in Table 9, is similar to that described for Case 1.

Table 7. Program Output for Case 2

```
PROGRAM WILL BE EXECUTED IN THE EMISSION MODE
6 1 3 0 3 0 0 0 0 0 1      0.000      0.000  0  3      0.000
          20.000      0.000    90.000     0.000     0.000
 900.000  1145.000      5.000

        SLANT PATH TO SPACE FROM ALTITUDE H1 = 20.000 KM, ZENITH ANGLE = 90.000 DEGREES

                 HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

             MODEL ATMOSPHERE 6 = 1962 US STANDARD

               HAZE MODEL  1 =     RURAL       VIS= 23.0KM

             SEASON =    SPRIG SUMM

             VERTICAL PROFILE AEROSOL MODEL =        STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1    ( 8.73 - 11.11 MICRONS )
```

HORIZONTAL PROFILES

ID	ALT	P	T	H2O	CO2+	O3	N2	H2O(10M)	HCLS	(N-1)	O3(UV)
1	0.00	1013.000	288.100	5.760E-01	3.294E-01	2.497E-03	7.385E-01	6.574E-03	9.481E-01	2.595E-04	2.520E-03
2	1.00	898.600	281.600	3.719E-01	7.776E-01	2.387E-03	6.014E-01	3.832E-03	8.604E-01	2.393E-04	2.524E-03
3	2.00	795.000	275.100	2.324E-01	6.480E-01	2.284E-03	4.875E-01	2.127E-03	7.792E-01	2.129E-04	2.520E-03
4	3.00	701.200	268.700	1.302E-01	5.373E-01	2.021E-03	3.929E-01	9.847E-04	7.037E-01	1.921E-04	2.333E-03
5	4.00	616.600	262.200	7.167E-02	4.437E-01	1.775E-03	3.152E-01	4.504E-04	6.341E-01	1.729E-04	2.147E-03
6	5.00	540.500	255.700	3.746E-02	3.649E-01	1.592E-03	2.515E-01	1.927E-04	5.703E-01	1.552E-04	2.147E-03
7	6.00	472.200	249.200	1.997E-02	2.983E-01	1.576E-03	1.995E-01	8.679E-05	5.109E-01	1.390E-04	2.100E-03
8	7.00	411.100	242.700	9.136E-03	2.428E-01	1.632E-03	1.573E-01	3.559E-05	4.567E-01	1.241E-04	2.287E-03
9	8.00	356.500	236.200	5.005E-03	1.964E-01	1.645E-03	1.232E-01	1.567E-05	4.070E-01	1.104E-04	2.427E-03
10	9.00	308.000	229.700	1.707E-03	1.580E-01	2.131E-03	9.590E-02	4.079E-06	3.616E-01	9.792E-05	3.313E-03
11	10.00	265.000	223.200	5.897E-04	1.263E-01	2.958E-03	7.412E-02	1.181E-06	3.201E-01	8.654E-05	4.200E-03
12	11.00	227.000	216.800	2.368E-04	[illegible]	3.493E-03	5.681E-02	4.288E-07	2.823E-01	7.525E-05	6.067E-03
13	12.00	194.000	216.600	9.379E-05	7.627E-02	4.038E-03	4.155E-02	1.543E-07	2.415E-01	6.434E-05	7.467E-03
14	13.00	165.800	216.600	3.319E-05	5.794E-02	4.029E-03	3.035E-02	6.169E-08	2.064E-01	5.499E-05	7.933E-03
15	14.00	141.700	216.600	1.588E-05	4.402E-02	4.229E-03	2.217E-02	2.415E-08	1.764E-01	4.699E-05	8.867E-03
16	15.00	121.100	216.600	1.182E-05	3.344E-02	4.389E-03	1.619E-02	1.769E-08	1.508E-01	4.016E-05	9.800E-03
17	16.00	103.500	216.600	8.691E-06	2.540E-02	4.711E-03	1.187E-02	1.281E-08	1.288E-01	3.433E-05	1.120E-02
18	17.00	88.500	216.600	5.435E-06	1.931E-02	5.162E-03	8.647E-03	9.334E-09	1.102E-01	2.935E-05	1.307E-02
19	18.00	75.650	216.600	4.728E-06	1.468E-02	5.541E-03	6.318E-03	6.749E-09	9.418E-02	2.509E-05	1.493E-02
20	19.00	64.670	216.600	4.106E-06	1.115E-02	5.692E-03	4.617E-03	5.796E-09	8.051E-02	2.145E-05	1.633E-02
21	20.00	55.290	216.600	3.567E-06	8.479E-03	5.804E-03	3.375E-03	4.981E-09	6.883E-02	1.830E-05	1.773E-02
22	21.00	47.290	217.600	3.772E-06	6.405E-03	5.448E-03	2.452E-03	4.686E-09	5.860E-02	1.559E-05	1.773E-02
23	22.00	40.470	218.600	3.169E-06	4.850E-03	5.248E-03	1.783E-03	4.387E-09	4.992E-02	1.329E-05	1.824E-02
24	23.00	34.670	219.600	3.116E-06	3.676E-03	4.803E-03	1.300E-03	4.171E-09	4.257E-02	1.133E-05	1.773E-02
25	24.00	29.720	220.600	2.994E-06	2.790E-03	4.274E-03	9.485E-04	3.878E-09	3.633E-02	9.673E-06	1.680E-02
26	25.00	25.490	221.600	2.637E-06	2.119E-03	3.793E-03	6.932E-04	3.660E-09	3.102E-02	6.502E-06	1.587E-02
27	30.00	11.970	226.500	7.514E-07	9.479E-04	1.642E-03	1.479E-04	9.944E-10	1.425E-02	2.988E-06	9.333E-03
28	35.00	5.746	236.500	1.624E-07	1.429E-04	6.674E-04	3.195E-05	1.943E-10	6.551E-03	1.380E-06	5.133E-03
29	40.00	2.871	253.400	3.531E-08	3.860E-05	2.272E-04	7.192E-06	3.942E-11	3.055E-03	6.574E-07	2.287E-03
30	45.00	1.491	264.200	9.178E-09	1.158E-05	5.882E-05	1.822E-06	9.676E-12	1.522E-03	3.328E-07	7.933E-04
31	50.00	.798	270.600	1.939E-09	3.751E-06	1.072E-05	5.032E-07	1.922E-12	7.950E-04	1.239E-07	1.867E-04
32	70.00	.055	219.700	2.406E-12	4.662E-08	8.259E-08	3.293E-09	1.653E-15	6.775E-05	9.787E-09	4.013E-06
33	100.00	.000	210.000	1.502E-16	5.422E-12	5.181E-12	1.046E-13	6.054E-20	3.862E-07	5.548E-11	2.007E-09
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

Table 7. Program Output for Case 2 (Cont.)

HORIZONTAL PROFILES

ID	ALT	P	T	H2O(KM)	HNO3	AER1	AER2	AER3	AER4	(AER1*RH)	RH
1	0.00	1013.000	288.100	8.479E-02	0.	1.580E-01	0.	0.	0.	7.226E+00	4.575E+01
2	1.00	898.600	281.600	5.997E-02	0.	9.910E-02	0.	0.	0.	4.862E+00	4.906E+01
3	2.00	795.000	275.100	3.393E-02	0.	6.210E-02	0.	0.	0.	3.238E+00	5.214E+01
4	3.00	701.200	268.700	2.432E-02	0.	0.	3.460E-02	0.	0.	0.	0.
5	4.00	616.600	262.200	1.469E-02	0.	0.	1.850E-02	0.	0.	0.	0.
6	5.00	540.500	255.700	8.494E-03	0.	0.	9.310E-03	0.	0.	0.	0.
7	6.00	472.200	249.200	5.135E-03	0.	0.	7.710E-03	0.	0.	0.	0.
8	7.00	411.100	242.700	2.795E-03	0.	0.	6.230E-03	0.	0.	0.	0.
9	8.00	356.500	236.200	1.512E-03	4.070E-05	0.	3.370E-03	0.	0.	0.	0.
10	9.00	308.000	229.700	6.266E-04	3.616E-06	0.	1.820E-03	0.	0.	0.	0.
11	10.00	265.000	223.200	2.502E-04	1.056E-05	0.	0.	1.140E-03	0.	0.	0.
12	11.00	227.000	216.800	1.167E-04	2.259E-05	0.	0.	7.990E-04	0.	0.	0.
13	12.00	194.000	216.600	4.525E-05	2.698E-05	0.	0.	6.410E-04	0.	0.	0.
14	13.00	165.800	216.600	1.481E-05	2.890E-05	0.	0.	5.170E-04	0.	0.	0.
15	14.00	141.700	216.600	7.502E-06	2.822E-05	0.	0.	4.420E-04	0.	0.	0.
16	15.00	121.100	216.600	5.496E-06	2.714E-05	0.	0.	3.950E-04	0.	0.	0.
17	16.00	103.500	216.600	3.979E-06	2.448E-05	0.	0.	3.820E-04	0.	0.	0.
18	17.00	88.500	216.600	2.901E-06	2.203E-05	0.	0.	4.250E-04	0.	0.	0.
19	18.00	75.650	216.600	2.095E-06	1.978E-05	0.	0.	5.200E-04	0.	0.	0.
20	19.00	64.670	216.600	1.794E-06	1.852E-05	0.	0.	5.810E-04	0.	0.	0.
21	20.00	55.290	216.600	1.533E-06	2.065E-05	0.	0.	5.890E-04	0.	0.	0.
22	21.00	47.290	217.600	1.390E-06	2.168E-05	0.	0.	5.020E-04	0.	0.	0.
23	22.00	40.470	218.600	1.257E-06	2.097E-05	0.	0.	4.200E-04	0.	0.	0.
24	23.00	34.670	219.600	1.144E-06	2.214E-05	0.	0.	3.000E-04	0.	0.	0.
25	24.00	29.720	220.600	1.071E-06	2.180E-05	0.	0.	1.980E-04	0.	0.	0.
26	25.00	25.490	221.600	9.214E-07	1.179E-05	0.	0.	1.310E-04	0.	0.	0.
27	30.00	11.970	226.500	2.184E-07	3.705E-06	0.	0.	3.320E-05	0.	0.	0.
28	35.00	5.746	236.500	3.431E-08	1.441E-07	0.	0.	0.	1.640E-05	0.	0.
29	40.00	2.871	253.400	4.906E-09	3.055E-07	0.	0.	0.	7.990E-06	0.	0.
30	45.00	1.491	264.200	9.787E-10	0.	0.	0.	0.	4.010E-06	0.	0.
31	50.00	.798	270.600	1.746E-11	0.	0.	0.	0.	2.100E-06	0.	0.
32	70.00	.055	219.700	4.779E-13	0.	0.	0.	0.	1.600E-07	0.	0.
33	100.00	.000	210.000	2.306E-17	0.	0.	0.	0.	9.310E-10	0.	0.
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

FROM POINT\ HEIGHT= 20.0000 KM, N= 21, NP= 1, REF. INDEX ABOVE & BELOW X= .1830E-04 .2145E-04, IF= 1
EQUIV. ABSORBER AMOUNTS PER KM AT X= .357E-05 .148E-02 .580E-02 .338E-02 .498E-08 .688E-01 0. .177E-01

TX(12-14) = 0. .589E-03 0.1

Table 7. Program Output for Case 2 (Cont.)

VERTICAL PROFILES

IC	ALT	H2O	CO2+ H2O(4M)	O3 HNO3	N2 AER2	H2O(10M) AER3	MOLS AER4	AER1	O3(UV)	PSI	PHI	BETA	THETA	RANGE DRANGE
21	20.000	3.921E-04	8.362E-01	6.759E-01	3.266E-01	5.463E-07	7.188E+00	0.	2.005E+00	-.0000	91.0135	1.0135	90.0000	113.1
	21.000		1.652E-04	2.393E-03	0.	6.155E-02	0.							113.06
22	21.000	5.462E-04	1.100E+00	8.879E-01	4.256E-01	7.600E-07	9.744E+00	0.	2.852E+00	.0088	91.4270	1.4358	88.9554	160.2
	22.000		2.274E-04	3.398E-03	0.	8.321E-02	0.							47.13
23	22.000	6.581E-04	1.257E+00	1.071E+00	4.809E-01	9.148E-07	1.141E+01	0.	3.502E+00	.0141	91.7458	1.7599	88.5763	196.4
	23.000		2.707E-04	4.177E-03	0.	9.612E-02	0.							36.18
24	23.000	7.468E-04	1.451E+00	1.208E+00	5.150E-01	1.038E-06	1.261E+01	0.	4.028E+00	.0176	92.0153	2.0331	88.2579	226.9
	24.000		3.037E-04	4.847E-03	0.	1.036E-01	0.							30.50
25	24.000	8.199E-04	1.417E+00	1.316E+00	5.368E-01	1.139E-06	1.351E+01	0.	4.467E+00	.0205	92.2531	2.2736	87.9875	253.7
	25.000		3.298E-04	5.285E-03	0.	1.080E-01	0.							26.67
26	25.000	9.790E-04	1.539E+00	1.587E+00	5.740E-01	1.254E-06	1.579E+01	0.	5.764E+00	.0251	93.1909	3.2161	87.7519	359.1
	30.000		3.812E-04	5.920E-03	0.	1.155E-01	0.							105.37
27	30.000	1.010E-03	1.565E+00	1.674E+00	5.801E-01	1.394E-06	1.659E+01	0.	6.332E+00	.0268	93.5086	3.9376	86.8127	439.9
	35.000		3.893E-04	6.103E-03	0.	1.155E-01	0.							80.79
28	35.000	1.016E-03	1.569E+00	1.702E+00	5.813E-01	1.401E-06	1.690E+01	0.	6.572E+00	.0301	94.5146	4.5447	86.0925	508.0
	40.000		3.903E-04	6.109E-03	0.	1.155E-01	7.963E-04							68.09
29	40.000	1.017E-03	1.570E+00	1.709E+00	5.815E-01	1.402E-06	1.703E+01	0.	6.656E+00	.0306	95.0481	5.0767	85.4860	568.[illegible]
	45.000		3.904E-04	6.109E-03	0.	1.155E-01	1.143E-03							59.99
30	45.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.709E+01	0.	6.679E+00	.0308	95.5306	5.5608	84.9521	622.2
	50.000		3.905E-04	6.109E-03	0.	1.155E-01	1.303E-03							54.24
31	50.000	1.117E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.714E+01	0.	6.688E+00	.0310	97.1353	7.1563	84.4731	803.5
	70.000		3.905E-04	6.109E-03	0.	1.155E-01	1.439E-03							181.31
32	70.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	.0314	99.0126	9.0436	82.8647	1017.1
	100.000		3.905E-04	5.109E-03	0.	1.155E-01	1.446E-03							213.58
33	100.000	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	.0316	176.5553	86.5863	60.988*******	
	********		3.905E-04	5.109E-03	0.	1.155E-01	1.446E-03							*******
34	********	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	.0309	176.5553	86.5863	3.4447*******	
	********		3.905E-04	6.109E-03	0.	1.155E-01	1.446E-03							..00

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AER1	OZONE(U-V) ATM CM NITRIC ACID*
W(1-8)=	.102E-02	.157E+01	.171E+01	.582E+00	.140E-05 .350E-03	.171E+02	0.	.669E+01 .611E-02

	AER2	AER3	AER4	R.H. MEAN
W(12-15)=	0.	1.155E-01	1.446E-03	0.*

Table 7. Program Output for Case 2 (Cont.)

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ICH      1     5    10    15
EXTINCTION AND ABSORPTION COEFFICIENTS
21 34
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CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH

	H2O	CO2+	O3	N2	H2O C	MOL S	AER1	O3 UV	H2O C	HNO3	TAVE
1	3.921E-04	8.362E-01	5.759E-01	3.256E-01	5.453E-07	7.188E+00	0.	2.305E+00	1.652E-04	2.393E-03	217.1.0
2	5.462E-04	1.100E+00	6.879E-01	4.256E-01	7.600E-07	9.740E+00	0.	2.852E+00	2.274E-04	3.398E-03	218.100
3	5.581E-04	1.253E+00	1.070E+00	4.809E-01	9.148E-07	1.141E+01	0.	3.502E+00	2.707E-04	4.177E-03	219.100
4	7.465E-04	1.351E+00	1.208E+00	5.150E-01	1.038E-06	1.261E+01	0.	4.028E+00	3.037E-04	4.847E-03	220.100
5	9.199E-04	1.417E+00	1.316E+00	5.358E-01	1.139E-06	1.351E+01	0.	4.467E+00	3.298E-04	5.285E-03	221.100
6	9.790E-04	1.539E+00	1.587E+00	5.740E-01	1.354E-06	1.579E+01	0.	5.764E+00	3.812E-04	6.020E-03	224.050
7	1.010E-03	1.557E+00	1.674E+00	5.801E-01	1.394E-06	1.659E+01	0.	6.332E+00	3.893E-04	6.105E-03	231.500
8	1.016E-03	1.569E+00	1.702E+00	5.813E-01	1.401E-06	1.690E+01	0.	6.572E+00	3.903E-04	6.109E-03	244.950
9	1.017E-03	1.570E+00	1.709E+00	5.815E-01	1.402E-06	1.703E+01	0.	6.656E+00	3.904E-04	6.109E-03	258.800
10	1.017E-03	1.571E+00	1.711E+00	5.815E-01	1.402E-06	1.709E+01	0.	6.679E+00	3.905E-04	6.109E-03	267.400
11	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.714E+01	0.	6.688E+00	3.905E-04	6.109E-03	245.150
12	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	3.905E-04	6.109E-03	214.850
13	1.017E-03	1.571E+00	1.711E+00	5.816E-01	1.402E-06	1.715E+01	0.	6.688E+00	3.905E-04	6.109E-03	210.000

ID	AER2	AER3	AER4
1	0.	6.155E-02	0.
2	0.	8.321E-02	0.
3	0.	9.617E-02	0.
4	0.	1.036E-01	0.
5	0.	1.080E-01	0.
6	0.	1.155E-01	0.
7	0.	1.155E-01	0.
8	0.	1.155E-01	7.963E-04
9	0.	1.155E-01	1.143E-03
10	0.	1.155E-01	1.303E-03
11	0.	1.155E-01	1.439E-03
12	0.	1.155E-01	1.446E-03
13	0.	1.155E-01	1.446E-03

Table 7. Program Output for Case 2 (Cont.)

FR(CM-1)	WVL(MICRON)	RADIANCE(WATTS/CM2-STER-XXX): PER CM-1	PER MICRON	INTEGRAL	TRANS
900.0	11.111111	.16164E-06	.13093E-04	.40410E-06	.931759
905.0	11.049724	.12192E-06	.99852E-05	.10137E-05	947745
910.0	10.989011	.10297E-06	.85266E-05	.15285E-05	.955162
915.0	10.928962	.86637E-07	.72534E-05	.19617E-05	.961666
920.0	10.869565	.60854E-07	.51507E-05	.22664E-05	.972621
925.0	10.810811	.26577E-07	.22740E-05	.23988E-05	.987833
930.0	10.752688	.31905E-07	.27594E-05	.25584E-05	.985119
935.0	10.695187	.39754E-07	.34754E-05	.27571E-05	.981171
940.0	10.638298	.47081E-07	.41601E-05	.29925E-05	.977301
945.0	10.582011	.55364E-07	.49442E-05	.32694E-05	.972640
950.0	10.526316	.15285E-06	.13795E-04	.40336E-05	.925223
955.0	10.471204	.25232E-06	.23012E-04	.52952E-05	.874511
960.0	10.416667	.32513E-06	.29964E-04	.69209E-05	.834569
965.0	10.362694	.42639E-06	.39707E-04	.90528E-05	.778423
970.0	10.309278	.55343E-06	.52072E-04	.11820E-04	.706579
975.0	10.256410	.67475E-06	64143E-04	.15194E-04	.634653
980.0	10.204082	.83156E-06	.84665E-04	.19601E-04	.511063
985.0	10.152284	.10724E-05	.10405E-03	.24964E-04	.393142
990.0	10.101010	.12275E-05	.12031E-03	.31101E-04	.277756
995.0	10.050251	.12792E-05	.12665E-03	.37497E-04	.227030
1000.0	10.000000	.13341E-05	.13341E-03	.44168E-04	.174697
1005.0	9.950249	.13591E-05	.13728E-03	.50964E-04	.140230
1010.0	9.900990	.13678E-05	.13953E-03	.57803E-04	.116348
1015.0	9.852217	.13719E-05	.14134E-03	.64662E-04	.095201
1020.0	9.803922	.13614E-05	.14164E-03	.71469E-04	.083967
1025.0	9.756098	.13408E-05	.14087E-03	.78173E-04	.086559
1030.0	9.708738	.13200E-05	.14004E-03	.84773E-04	.077442
1035.0	9.661836	.13220E-05	.14161E-03	.91383E-04	.055971
1040.0	9.615385	.12896E-05	.13948E-03	.97831E-04	.063006
1045.0	9.569378	.12018E-05	.13124E-03	.10364E-03	.116238
1050.0	9.523810	.12359E-05	.13626E-03	.11002E-03	.068097
1055.0	9.478673	.12228E-05	.13610E-03	.11613E-03	.059749
1060.0	9.433962	.11856E-05	.13321E-03	.12206E-03	.071593
1065.0	9.389671	.11397E-05	.12926E-03	.12776E-03	.094354
1070.0	9.345794	.10455E-05	.11977E-03	.13299E-03	.160674
1075.0	9.302326	.63249E-06	.73093E-04	.13615E-03	.503533
1080.0	9.259259	.46808E-06	.54597E-04	.13849E-03	.628418
1085.0	9.216590	.44050E-06	.51856E-04	.14069E-03	.645048
1090.0	9.174312	.41827E-06	.49694E-04	.14278E-03	.657076
1095.0	9.132420	.40534E-06	.48601E-04	.14481E-03	.661553
1100.0	9.090909	.39039E-06	.47238E-04	.14676E-03	.667975
1105.0	9.049774	.38683E-06	.47233E-04	.14870E-03	.664648
1110.0	9.009009	.38916E-06	.47949E-04	.15064E-03	.655836
1115.0	8.968610	.39428E-06	.46521E-04	.15259E-03	.647215
1120.0	8.928571	.38734E-06	.48588E-04	.15453E-03	.642639
1125.0	8.888889	.38452E-06	.48666E-04	.15645E-03	.637666
1130.0	8.849558	.37413E-06	.47772E-04	.15832E-03	.641652
1135.0	8.810573	.34808E-06	.44840E-04	.16006E-03	.660839
1140.0	8.771930	.30124E-06	.39149E-04	.16157E-03	.700852
1145.0	8.733624	.25515E-06	.33451E-04	.16221E-03	.741014

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 113.93AVERAGE TRANSMITTANCE = .5350
INTEGRATED RADIANCE = .16221E-03WATT CM -2 SR
RADMIN 925.000 .26577E-07
RADMAX 1015.000 .13719E-05
2

Table 8. Program Output for Case 3

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PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
6  1  1  3  0  0  0  0  0  0  0     0.000     0.000  0  0     0.000
              0.000      0.000     0.000     1.000     0.000
 900.000  1145.000      5.000

        HORIZONTAL PATH, ALTITUDE =  0.000 KM,RANGE =  1.000 KM

                HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

             MODEL ATMOSPHERE 6 = 1962 US STANDARD

              HAZE MODEL  1 =    RURAL       VIS= 23.0KM

             SEASON =    SPRIG SUMM

             VERTICAL PROFILE AEROSOL MODEL =        STRAT BKGP

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   ( 8.73 - 11.11 MICRONS )


        HORIZONTAL PROFILES
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ID	ALT	P	T	H2O	CO2+	O3	N2	H2O(10M)	MOLS	(N-1)	O3(UV)
1	0.00	1013.000	288.100	5.763E-01	9.294E-01	2.493E-13	7.385E-01	6.574E-03	9.481E-01	2.595E-04	2.520E-03
2	1.00	898.600	281.600	3.719E-01	7.776E-01	2.387E-13	6.014E-01	3.832E-03	8.604E-01	2.353E-04	2.520E-03
3	2.00	795.000	275.100	2.324E-01	6.480E-01	2.284E-03	4.875E-01	2.127E-03	7.792E-01	2.129E-04	2.520E-03
4	3.00	701.200	268.700	1.302E-01	5.373E-01	2.021E-03	3.929E-01	9.847E-04	7.037E-01	1.921E-04	2.333E-03
5	4.00	616.600	262.200	7.167E-02	4.437E-01	1.775E-03	3.152E-01	4.504E-04	6.341E-01	1.729E-04	2.147E-03
6	5.00	540.500	255.700	3.746E-02	3.648E-01	1.692E-03	2.515E-01	1.927E-04	5.730E-01	1.552E-04	2.147E-03
7	6.00	472.200	249.200	1.997E-02	2.983E-01	1.576E-03	1.995E-01	8.679E-05	5.109E-01	1.390E-04	2.100E-03
8	7.00	411.100	242.700	9.436E-03	2.428E-01	1.632E-03	1.573E-01	3.559E-05	4.567E-01	1.241E-04	2.287E-03
9	8.00	356.500	236.200	5.015E-03	1.964E-01	1.645E-03	1.232E-01	1.567E-05	4.070E-01	1.104E-04	2.427E-03
10	9.00	308.000	229.700	1.707E-03	1.580E-01	2.131E-03	9.591E-02	4.079E-06	3.616E-01	9.792E-05	3.313E-03
11	10.00	265.000	223.200	5.897E-04	1.263E-01	2.558E-03	7.412E-02	1.181E-06	3.201E-01	8.654E-05	4.200E-03
12	11.00	227.000	216.800	2.361E-04	1.003E-01	3.493E-03	5.681E-02	4.288E-07	2.823E-01	7.525E-05	6.067E-03
13	12.00	194.000	216.600	9.273E-05	7.627E-02	4.036E-03	4.155E-02	1.543E-07	2.415E-01	6.434E-05	7.467E-03
14	13.00	165.800	216.600	3.919E-05	5.794E-02	4.029E-03	3.035E-02	6.189E-08	2.064E-01	5.499E-05	7.933E-03
15	14.00	141.700	216.600	1.588E-05	4.402E-02	4.229E-03	2.217E-02	2.415E-08	1.764E-01	4.699E-05	8.867E-03
16	15.00	121.100	216.600	1.182E-05	3.344E-02	4.389E-03	1.619E-02	1.769E-08	1.508E-01	4.016E-05	9.800E-03
17	16.00	103.500	216.600	8.591E-06	2.540E-02	4.711E-03	1.183E-02	1.281E-08	1.288E-01	3.433E-05	1.120E-02
18	17.00	88.500	216.600	6.435E-06	1.931E-02	5.162E-03	8.647E-03	9.334E-09	1.102E-01	2.935E-05	1.307E-02
19	18.00	75.650	216.600	4.728E-06	1.468E-02	5.541E-03	6.318E-03	6.749E-09	9.418E-02	2.509E-05	1.493E-02
20	19.00	64.670	216.600	4.106E-06	1.115E-02	5.692E-03	4.617E-03	5.796E-09	8.051E-02	2.145E-05	1.633E-02
21	20.00	55.290	216.600	3.965E-06	8.479E-03	5.894E-03	3.375E-03	4.981E-09	6.883E-02	1.830E-05	1.773E-02
22	21.00	47.290	217.600	3.372E-06	6.409E-03	5.448E-03	2.452E-03	4.686E-09	5.860E-02	1.559E-05	1.773E-02
23	22.00	40.470	218.600	3.169E-06	4.850E-03	5.248E-03	1.783E-03	4.387E-09	4.992E-02	1.329E-05	1.820E-02
24	23.00	34.670	219.600	3.016E-06	3.676E-03	4.803E-03	1.300E-03	4.171E-09	4.257E-02	1.133E-05	1.773E-02
25	24.00	29.720	220.600	2.804E-06	2.790E-03	4.274E-03	9.488E-04	3.878E-09	3.633E-02	9.673E-06	1.680E-02
26	25.00	25.490	221.600	2.637E-06	2.119E-03	3.793E-03	6.932E-04	3.660E-09	3.102E-02	6.502E-06	1.587E-02
27	30.00	11.970	226.500	7.614E-07	5.479E-04	1.642E-03	1.479E-04	9.944E-10	1.425E-02	2.988E-06	9.333E-03
28	35.00	5.746	236.500	1.624E-07	1.429E-04	6.574E-04	3.195E-05	1.943E-10	6.551E-03	1.380E-06	5.133E-03
29	40.00	2.871	253.400	3.531E-08	3.860E-05	2.222E-04	7.192E-06	3.942E-11	3.055E-03	6.574E-07	2.287E-03
30	45.00	1.491	264.200	9.178E-09	1.158E-05	5.882E-05	1.822E-06	9.676E-12	1.522E-03	3.328E-07	7.933E-04
31	50.00	.798	270.600	1.933E-09	3.751E-06	1.072E-05	5.032E-07	1.922E-12	7.950E-04	1.239E-07	1.867E-04
32	70.00	.055	219.700	2.405E-12	4.662E-08	8.259E-08	3.293E-09	1.653E-15	6.775E-05	9.787E-09	4.013E-06
33	100.00	.000	210.000	1.502E-16	5.422E-12	5.181E-12	1.046E-13	6.054E-20	3.862E-07	5.548E-11	2.007E-09
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

Table 8. Program Output for Case 3 (Cont.)

HORIZONTAL PROFILES

IC	ALT	P	T	H2O(4M)	HNO3	AER1	AER2	AER3	AER4	(AER1*RH)	RH
1	0.00	1013.000	288.100	5.479E-02	0.	1.580E-01	0.	0.	0.	7.228E+00	4.575E+01
2	1.00	898.600	281.600	5.897E-02	0.	9.910E-02	0.	0.	0.	4.862E+00	4.506E+01
3	2.00	795.000	275.100	3.393E-02	0.	6.210E-02	0.	0.	0.	3.238E+00	5.214E+01
4	3.00	701.200	268.700	2.432E-02	0.	0.	3.460E-02	0.	0.	0.	0.
5	4.00	616.600	262.200	1.469E-02	0.	0.	1.850E-02	0.	0.	0.	0.
6	5.00	540.500	255.700	8.494E-03	0.	0.	9.31[illegible]E-03	0.	0.	0.	0.
7	6.00	472.200	249.200	5.039E-03	0.	0.	7.710E-03	0.	0.	0.	0.
8	7.00	411.100	242.700	2.796E-03	0.	0.	6.230E-03	0.	0.	0.	0.
9	8.00	356.500	236.200	1.612E-03	4.070E-55	0.	3.370E-03	0.	0.	0.	0.
10	9.00	308.000	229.700	5.266E-04	3.616E-06	0.	1.820E-03	0.	0.	0.	0.
11	10.00	265.000	223.200	2.502E-04	1.056E-05	0.	0.	1.140E-03	0.	0.	0.
12	11.00	227.000	216.800	1.167E-04	2.259E-05	0.	0.	7.990E-04	0.	0.	0.
13	12.00	194.000	216.600	4.525E-05	2.898E-05	0.	0.	6.410E-04	0.	0.	0.
14	13.00	165.800	216.600	1.881E-05	2.890E-05	0.	0.	5.170E-04	0.	0.	0.
15	14.00	141.700	216.600	7.502E-06	2.822E-05	0.	0.	4.420E-04	0.	0.	0.
16	15.00	121.100	216.600	5.495E-06	2.714E-05	0.	0.	3.950E-04	0.	0.	0.
17	16.00	103.500	216.600	3.379E-06	2.448E-05	0.	0.	3.820E-04	0.	0.	0.
18	17.00	88.500	216.600	2.901E-06	2.203E-05	0.	0.	4.250E-04	0.	0.	0.
19	18.00	75.650	216.600	2.098E-06	1.978E-05	0.	0.	5.200E-04	0.	0.	0.
20	19.00	64.670	216.600	1.794E-06	1.852E-05	0.	0.	5.810E-04	0.	0.	0.
21	20.00	55.290	216.600	1.537E-06	2.065E-05	0.	0.	5.890E-04	0.	0.	0.
22	21.00	47.290	217.600	1.390E-06	2.165E-05	0.	0.	5.020E-04	0.	0.	0.
23	22.00	40.470	218.600	1.253E-06	2.097E-05	0.	0.	4.200E-04	0.	0.	0.
24	23.00	34.670	219.600	1.144E-06	2.214E-05	0.	0.	3.300E-04	0.	0.	0.
25	24.00	29.720	220.600	1.021E-06	2.180E-05	0.	0.	1.980E-04	0.	0.	0.
26	25.00	25.430	221.600	9.714E-07	1.179E-05	0.	0.	1.310E-04	0.	0.	0.
27	30.00	11.970	226.500	2.184E-07	3.705E-06	0.	0.	3.320E-05	0.	1.	4.
28	35.00	5.746	235.500	3.431E-08	1.441E-07	0.	0.	0.	1.640E-05	0.	0.
29	40.00	2.571	253.400	4.306E-09	3.055E-57	0.	0.	0.	7.990E-06	0.	0.
30	45.00	1.491	264.200	9.787E-10	0.	0.	0.	0.	4.010E-06	0.	0.
31	50.00	.798	270.650	1.743E-10	0.	0.	0.	0.	2.100E-06	0.	0.
32	70.00	.055	219.700	4.779E-13	0.	0.	0.	0.	1.600E-07	0.	0.
33	100.00	.000	210.000	2.706E-17	0.	0.	0.	0.	9.310E-10	0.	0.
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

FROM POINT\ HEIGHT= 0.0000 KM,N= 1,NP= 1,REF. INDEX ABOVE & BELOW X= .2595E-03 0. ,IP= 1
EQUIV. ABSORBER AMOUNTS PER KM AT X= .576E+00 .929E+00 .249E-02 .739E+00 .657E-02 .948E+00 .158E+00 .252E-02

TX(12-14) = 0. 0. 0.1

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	HCL KM	SCAT AER1	OZONE(U-V) ATM CM / NITRIC ACID*
W(1-8)=	.576E+00	.929E+00	.249E-02	.739E+00	.657E-02 .848E-01	.948E+00	.156E+00	.252E-02 0.

	AER2	AER3	AER4	R.H. MEAN
W(12-15)=	0.	0.	0.	4.575E+01

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EXTINCTION AND ABSORPTION COEFFICIENTS

Table 8. Program Output for Case 3 (Cont.)

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION	NITRIC ACID TRANS
900	11.1111	.9117	.9776	1.0000	1.0000	1.0000	.9434	1.0000	.9885	.0042	.2207	1.0000
905	11.0497	.9100	.9753	.9994	1.0000	1.0000	.9446	1.0000	.9884	.0042	.6704	1.0000
910	10.9890	.9100	.9745	.9992	1.0000	1.0000	.9456	1.0000	.9883	.0043	1.1204	1.0000
915	10.9290	.9100	.9741	.9985	1.0000	1.0000	.9467	1.0000	.9882	.0044	1.5743	1.0000
920	10.8696	.9116	.9756	.9978	1.0000	1.0000	.9477	1.0000	.9881	.0045	2.0125	1.0000
925	10.8108	.9201	.9854	.9963	1.0000	1.0000	.9486	1.0000	.9879	.0046	[illegible]	1.0000
930	10.7527	.9205	.9869	.9945	1.0000	1.0000	.9496	1.0000	.9878	.0047	[illegible]	1.0000
935	10.6952	.9204	.9861	.9923	1.0000	1.0000	.9505	1.0000	.9877	.0049	3.2[illegible]75	1.0000
940	10.6383	.9175	.9859	.9906	1.0000	1.0000	.9513	1.0000	.9875	.0050	3.6197	1.0000
945	10.5820	.9125	.9814	.9891	1.0000	1.0000	.9521	1.0000	.9874	.0051	4.0571	1.0000
950	10.5263	.9094	.9783	.9881	.9999	1.0000	.9529	1.0000	.9872	.0052	4.5101	1.0000
955	10.4712	.9075	.9753	.9866	.9998	1.0000	.9537	1.0000	.9871	.0053	4.9728	1.0000
960	10.4167	.9066	.9741	.9884	.9997	1.0000	.9544	1.0000	.9869	.0054	5.4356	1.0000
965	10.3627	.9064	.9737	.9881	.9996	1.0000	.9551	1.0000	.9868	.0055	5.9[illegible]75	1.0000
970	10.3093	.9046	.9733	.9862	.9993	1.0000	.9558	1.0000	.9866	.0057	6.3847	1.0000
975	10.2564	.9058	.9745	.9862	.9989	1.0000	.9565	1.0000	.9865	.0058	6.8558	1.0000
980	10.2041	.9115	.9787	.9886	.9980	1.0000	.9571	1.0000	.9863	.0059	7.2576	1.0000
985	10.1523	.9163	.9830	.9924	.9966	1.0000	.9577	1.0000	.9862	.0060	7.7[illegible]64	1.0000
990	10.1010	.9229	.9865	.9959	.9940	1.0000	.9583	1.0000	.9860	.0061	8.3917	1.0000
995	10.0503	.9180	.9809	.9984	.9916	1.0000	.9588	1.0000	.9859	.0062	8.5[illegible]19	1.0000
1000	10.0000	.9089	.9745	.9992	.9869	1.0000	.9594	1.0000	.9857	.0063	8.9581	1.0000
1005	9.9502	.9023	.9714	.9996	.9824	1.0000	.9599	1.0000	.9854	.0067	9.4466	1.0000
1010	9.9010	.8931	.9658	.9995	.9780	1.0000	.9604	1.0000	.9850	.0071	9.9809	1.0000
1015	9.8522	.8818	.9579	.9990	.9729	1.0000	.9609	1.0000	.9847	.0075	10.5719	1.0000
1020	9.8039	.8825	.9641	.9983	.9693	1.0000	.9613	1.0000	.9843	.0079	11.1594	1.0000
1025	9.7561	.8787	.9633	.9967	.9674	1.0000	.9618	1.0000	.9840	.0083	11.7657	1.0000
1030	9.7087	.8777	.9647	.9953	.9659	1.0000	.9622	1.0000	.9836	.0086	12.3770	1.0000
1035	9.6618	.8675	.9698	.9924	.9522	1.0000	.9625	1.0000	.9833	.0090	13.[illegible]397	1.0000
1040	9.6154	.8724	.9718	.9902	.9577	1.0000	.9634	1.0000	.9830	.0094	13.6777	1.0000
1045	9.5694	.8885	.9726	.9862	.9785	1.0000	.9634	1.0000	.9826	.0097	14.2352	1.0000
1050	9.5238	.8693	.9698	.9850	.9612	1.0000	.9638	1.0000	.9823	.0101	14.8667	1.0000
1055	9.4787	.8604	.9664	.9838	.9559	1.0000	.9641	1.0000	.9820	.0105	15.5665	1.0000
1060	9.4340	.8610	.9595	.9836	.9635	1.0000	.9644	1.0000	.9817	.0108	15.2818	1.0000
1065	9.3897	.8662	.9563	.9829	.9734	1.0000	.9648	1.0000	.9813	.0112	16.9548	1.0000
1070	9.3458	.8793	.9602	.9812	.9858	1.0000	.9651	1.0000	.9810	.0115	17.5543	1.0000
1075	9.3023	.8910	.9613	.9809	.9980	1.0000	.9654	1.0000	.9807	.0119	18.0992	1.0000
1080	9.2593	.9007	.9692	.9826	.9989	1.0000	.9557	1.0000	.9804	.0122	18.5957	1.0000
1085	9.2166	.9053	.9692	.9875	.9990	1.0000	.9659	1.0000	.9801	.0126	19.0689	1.0000
1090	9.1743	.9045	.9641	.9917	.9990	1.0000	.9662	1.0000	.9800	.0125	19.5463	1.0000
1095	9.1324	.9020	.9569	.9961	.9990	1.0000	.9665	1.0000	.9800	.0123	20.0364	1.0000
1100	9.0909	.8930	.9450	.9983	.9990	1.0000	.9667	1.0000	.9801	.0120	20.5714	1.0000
1105	9.0498	.8846	.9348	.9995	.9990	1.0000	.9670	1.0000	.9801	.0117	21.1484	1.0000
1110	9.0090	.8828	.9320	.9997	.9990	1.0000	.9672	1.0000	.9801	.0115	21.7367	1.0000
1115	8.9686	.8809	.9385	.9999	.9989	1.0000	.9674	1.0000	.9802	.0113	22.2921	1.0000
1120	8.9286	.8952	.9450	.9997	.9989	1.0000	.9676	1.0000	.9803	.0112	22.8162	1.0000
1125	8.8889	.9027	.9530	.9993	.9989	1.0000	.9678	1.0000	.9804	.0111	23.3[illegible]29	1.0000
1130	8.8496	.9080	.9589	.9987	.9989	1.0000	.9680	1.0000	.9805	.0110	23.7629	1.0000
1135	8.8106	.9003	.9517	.9973	.9990	1.0000	.9682	1.0000	.9806	.0109	24.2613	1.0000
1140	8.7719	.8944	.9473	.9948	.9992	1.0000	.9684	1.0000	.9808	.0108	24.7693	1.0000
1145	8.7336	.8891	.9442	.9917	.9994	1.0000	.9686	1.0000	.9809	.0107	25.[illegible]665	1.0000

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 25.07AVERAGE TRANSMITTANCE = .8977
2

Table 9. Program Output for Case 4

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PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
2  3  2  0  0  0  0  0  0  0  1      0.000      0.000  0  0       0.000
           12.000      0.000   180.000      0.000      0.000
       H1= 12.000KM,H2=  0.000KM,ANGLE=180.0000GEOM. RANGE =  12.00KM,BETA=  .00000
 900.000  1145.000      5.000

       SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 = 12.000 KM H2 =  0.000 KM,ZENITH ANGLE =180.000 DEGREES

               HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

            MODEL ATMOSPHERE 2 = MIDLATITUDE SUMMER

             HAZE MODEL  3 =  MARITIME      VIS= 23.0KM

            SEASON =    SPRIG SUMM

            VERTICAL PROFILE AEROSOL MODEL =       STRAT BKGR

       FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   ( 8.73 - 11.11 MICRONS )

       HORIZONTAL PROFILES
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ID	ALT	P	T	H2O	CO2+	O3	N2	H2O(10M)	MOLS	(N-1)	O3(UV)
1	0.00	1013.000	294.000	1.354E+00	9.038E-01	2.759E-03	7.164E-01	3.013E-02	9.291E-01	2.533E-04	2.800E-03
2	1.00	902.000	290.000	8.155E-01	7.517E-01	2.641E-03	5.798E-01	1.460E-02	6.387E-01	2.290E-04	2.800E-03
3	2.00	802.000	285.000	4.691E-01	5.268E-01	2.529E-03	4.705E-01	6.646E-03	7.588E-01	2.073E-04	2.800E-03
4	3.00	710.000	279.000	2.374E-01	5.215E-01	2.499E-03	3.807E-01	2.467E-03	6.862E-01	1.875E-04	2.893E-03
5	4.00	628.000	273.000	1.235E-01	4.335E-01	2.467E-03	3.077E-01	9.847E-04	6.203E-01	1.694E-04	2.987E-03
6	5.00	554.000	267.000	5.869E-02	3.589E-01	2.430E-03	2.476E-01	3.448E-04	5.595E-01	1.526E-04	3.080E-03
7	6.00	487.000	261.000	3.221E-02	2.955E-01	2.424E-03	1.980E-01	1.585E-04	5.031E-01	1.370E-04	3.220E-03
8	7.00	426.000	255.000	1.750E-02	2.414E-01	2.505E-03	1.568E-01	7.340E-05	4.505E-01	1.228E-04	3.500E-03
9	8.00	372.000	248.000	8.303E-03	1.978E-01	2.518E-03	1.247E-01	3.159E-05	4.045E-01	1.099E-04	3.667E-03
10	9.00	324.000	242.000	4.542E-03	1.607E-01	2.606E-03	9.814E-02	1.384E-05	3.610E-01	9.817E-05	4.013E-03
11	10.00	281.000	235.000	2.160E-03	1.384E-01	2.592E-03	7.714E-02	5.677E-06	3.224E-01	8.741E-05	4.200E-03
12	11.00	243.000	229.000	6.590E-04	1.048E-01	3.004E-03	5.997E-02	1.355E-06	2.861E-01	7.756E-05	5.133E-03
13	12.00	209.000	222.000	1.591E-04	8.400E-02	3.105E-03	4.648E-02	2.752E-07	2.539E-01	6.856E-05	5.600E-03
14	13.00	179.000	216.000	4.204E-05	6.650E-02	3.668E-03	3.552E-02	6.665E-08	2.235E-01	5.953E-05	7.000E-03
15	14.00	153.000	216.000	2.020E-05	5.053E-02	4.133E-03	2.595E-02	3.114E-08	1.910E-01	5.075E-05	8.400E-03
16	15.00	130.000	216.000	1.731E-05	3.809E-02	4.088E-03	1.874E-02	2.005E-08	1.623E-01	4.322E-05	8.867E-03
17	16.00	111.000	216.000	9.723E-06	2.882E-02	4.241E-03	1.366E-02	1.441E-08	1.386E-01	3.694E-05	9.800E-03
18	17.00	95.000	216.000	7.395E-06	2.195E-02	4.555E-03	1.001E-02	1.080E-08	1.186E-01	3.160E-05	1.120E-02
19	18.00	81.200	216.000	5.733E-06	1.668E-02	4.990E-03	7.310E-03	8.250E-09	1.014E-01	2.697E-05	1.307E-02
20	19.00	69.500	217.000	4.574E-06	1.262E-02	5.354E-03	5.318E-03	5.941E-09	8.636E-02	2.298E-05	1.493E-02
21	20.00	59.500	218.000	3.884E-06	9.556E-03	5.341E-03	3.871E-03	5.464E-09	7.360E-02	1.953E-05	1.587E-02
22	21.00	51.000	219.000	3.874E-06	7.251E-03	5.312E-03	2.825E-03	5.355E-09	6.279E-02	1.671E-05	1.680E-02
23	22.00	43.700	220.000	3.321E-06	5.499E-03	4.989E-03	2.060E-03	4.613E-09	5.356E-02	1.425E-05	1.680E-02
24	23.00	37.600	222.000	3.059E-06	4.174E-03	4.429E-03	1.504E-03	4.233E-09	4.567E-02	1.215E-05	1.587E-02
25	24.00	32.200	223.000	2.952E-06	3.163E-03	3.914E-03	1.096E-03	4.082E-09	3.894E-02	1.038E-05	1.493E-02
26	25.00	27.700	224.000	2.871E-06	2.415E-03	3.452E-03	8.055E-04	3.988E-09	3.334E-02	6.975E-06	1.400E-02
27	30.00	13.200	234.000	7.763E-07	6.217E-04	1.696E-03	1.713E-04	1.007E-09	1.521E-02	3.216E-06	9.333E-03
28	35.00	6.520	245.000	1.231E-07	1.698E-04	5.830E-04	3.901E-05	1.464E-10	7.176E-03	1.531E-06	4.293E-03
29	40.00	3.330	258.000	2.569E-08	4.881E-05	1.966E-04	9.417E-06	2.880E-11	3.480E-03	7.524E-07	1.913E-03
30	45.00	1.760	270.000	6.265E-09	1.502E-05	4.785E-05	2.457E-06	6.682E-12	1.758E-03	3.859E-07	6.067E-04
31	50.00	.951	276.000	1.187E-09	4.964E-06	1.232E-05	6.942E-07	1.191E-12	9.291E-04	1.454E-07	2.007E-04
32	70.00	.067	218.000	2.587E-12	5.632E-08	8.944E-08	4.923E-09	1.872E-15	6.300E-05	1.198E-08	4.013E-06
33	100.00	.000	210.000	1.499E-16	5.397E-12	5.175E-12	1.041E-13	6.038E-20	3.852E-07	5.533E-11	2.007E-09
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

Table 9. Program Output for Case 4 (Cont.)

HORIZONTAL PROFILES

IC	ALT	P	T	H2O(4M)	HNO3	AER1	AER2	AER3	AER4	(AER1*RH)	RH
1	0.00	1013.000	294.000	1.971E-01	0.	1.580E-01	0.	0.	0.	1.211E+01	7.665E+01
2	1.00	902.000	290.000	1.203E-01	0.	9.910E-02	0.	0.	0.	6.380E+00	6.436E+01
3	2.00	802.000	285.000	7.159E-02	0.	6.210E-02	0.	0.	0.	3.445E+00	5.548E+01
4	3.00	710.000	279.000	3.825E-02	0.	0.	3.460E-02	0.	0.	0.	0.
5	4.00	628.000	273.000	2.134E-02	0.	0.	1.850E-02	0.	0.	0.	0.
6	5.00	554.000	267.000	1.094E-02	0.	0.	9.310E-03	0.	0.	0.	0.
7	6.00	487.000	261.000	5.558E-03	0.	0.	7.710E-03	0.	0.	0.	0.
8	7.00	426.000	255.000	3.215E-03	0.	0.	6.230E-03	0.	0.	0.	0.
9	8.00	372.000	248.000	2.247E-03	4.045E-55	0.	3.370E-03	0.	0.	0.	0.
10	9.00	324.000	242.000	1.278E-03	3.610E-06	0.	1.820E-03	0.	0.	0.	0.
11	10.00	281.000	235.000	6.971E-04	1.064E-05	0.	0.	1.140E-03	0.	0.	0.
12	11.00	243.000	229.000	2.496E-04	2.289E-05	0.	0.	7.990E-04	0.	0.	0.
13	12.00	209.000	222.000	6.793E-05	3.046E-05	0.	0.	6.410E-04	0.	0.	0.
14	13.00	179.000	216.000	2.166E-05	3.128E-05	0.	0.	5.170E-04	0.	0.	0.
15	14.00	153.000	216.000	9.912E-06	3.056E-05	0.	0.	4.420E-04	0.	0.	0.
16	15.00	130.000	216.000	6.336E-06	2.921E-05	0.	0.	3.950E-04	0.	0.	0.
17	16.00	111.000	216.000	4.556E-06	2.633E-05	0.	0.	3.820E-04	0.	0.	0.
18	17.00	95.000	216.000	3.412E-06	2.372E-05	0.	0.	4.250E-04	0.	0.	0.
19	18.00	81.200	216.000	2.504E-06	2.129E-05	0.	0.	5.200E-04	0.	0.	0.
20	19.00	69.500	217.000	2.172E-06	1.986E-05	0.	0.	5.810E-04	0.	0.	0.
21	20.00	59.500	218.000	1.621E-06	2.208E-05	0.	0.	5.890E-04	0.	0.	0.
22	21.00	51.000	219.000	1.531E-06	2.323E-05	0.	0.	5.020E-04	0.	0.	0.
23	22.00	43.700	220.000	1.276E-06	2.250E-05	0.	0.	4.200E-04	0.	0.	0.
24	23.00	37.600	222.000	1.100E-06	2.375E-05	0.	0.	3.000E-04	0.	0.	0.
25	24.00	32.200	223.000	1.018E-06	2.336E-05	0.	0.	1.980E-04	0.	0.	0.
26	25.00	27.700	224.000	9.527E-07	1.267E-05	0.	0.	1.310E-04	0.	0.	0.
27	30.00	13.200	234.000	1.985E-07	3.955E-06	0.	0.	3.320E-05	0.	0.	0.
28	35.00	6.520	245.000	2.195E-08	1.579E-07	0.	0.	0.	1.640E-05	0.	0.
29	40.00	3.330	258.000	3.321E-09	3.480E-57	0.	0.	0.	7.990E-06	0.	0.
30	45.00	1.760	270.000	6.146E-10	0.	0.	0.	0.	4.010E-06	0.	0.
31	50.00	.951	276.000	9.877E-11	0.	0.	0.	0.	2.100E-08	0.	0.
32	70.00	.067	218.000	5.689E-13	0.	0.	0.	0.	1.600E-07	0.	0.
33	100.00	.000	210.000	2.300E-17	0.	0.	0.	0.	9.310E-10	0.	0.
34	99999.00	0.000	210.000	0.	0.	0.	0.	0.	0.	0.	0.

```
FROM POINT\ HEIGHT=   12.0000 KM,N= 13,NP= 1,REF. INDEX ABOVE & BELOW X=  .6856E-04  .7756E-04,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .155E-03  .840E-01  .310E-02  .465E-01  .275E-06  .254E+0_ 0.          .56_E-02


    TX(12-14)= 0.          .6415-03 0.1


FROM POINT\ HEIGHT=    0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X=  .2533E-03 0.          ,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .135E+01  .904E+00  .276E-02  .716E+00  .301E-01  .929E+00  .152E+00  .380E-02


    TX(12-14)= 0.          0.          0.1

HMIN =  -6371.230
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Table 9. Program Output for Case 4 (Cont.)

VERTICAL PROFILES

IC	ALT	H2O	CO2+ H2O(4M)	O3 HNO3	N2 AER2	H2O(10M) AER3	MOLS AER4	AER1	O3(UV)	PSI	PHI	BETA	THETA	RANGE ORANGE
12	12.000 11.000	3.518E-04	9.400E-02 1.365E-04	3.054E-03 2.650E-05	5.294E-02 0.	6.773E-07 7.171E-04	2.697E-01 0.	0.	5.363E-03	.0000	-.0000	-.0000	180.0000	1.0 1.00
11	11.000 10.000	1.616E-03	2.111E-01 5.657E-04	5.547E-03 4.249E-05	1.211E-01 0.	3.694E-06 1.677E-03	5.736E-01 0.	0.	1.001E-02	.0000	-.0000	-.0000	180.0000	2.0 1.00
10	10.000 9.000	4.821E-03	3.561E-01 1.524E-03	8.445E-03 4.699E-05	2.084E-01 0.	1.286E-05 1.677E-03	9.149E-01 0.	0.	1.412E-02	.0000	-.0000	-.0000	180 0000	3.0 1.00
9	9.000 8.000	1.130E-02	5.347E-01 3.241E-03	1.101E-02 4.902E-05	3.192E-01 2.516E-03	3.437E-05 1.677E-03	1.297E+00 0.	0.	1.797E-02	.0000	-.0000	-.0000	180.0000	4.0 1.00
8	8.000 7.000	2.402E-02	7.536E-01 6.246E-03	1.352E-02 4.902E-05	4.594E-01 7.170E-03	8.396E-05 1.677E-03	1.724E+00 0.	0.	2.156E-02	.0000	-.0000	-.0000	180.0000	5.0 1.00
7	7.000 6.000	4.813E-02	1.121E+00 1.137E-02	1.599E-02 4.902E-05	6.360E-01 1.411E-02	1.946E-04 1.677E-03	2.201E+00 0.	0.	2.492E-02	.0000	-.0000	-.0000	180 0000	6.0 1.00
6	6.000 5.000	9.226E-02	1.347E+00 1.994E-02	1.541E-02 4.902E-05	8.579E-01 2.260E-02	4.344E-04 1.677E-03	2.731E+00 0.	0.	2.807E-02	.0000	-.0000	-.0000	180.0000	7.0 1.00
5	5.000 4.000	1.794E-01	1.742E+00 3.550E-02	2.385E-02 4.902E-05	1.134E+00 3.598E-02	1.044E-03 1.677E-03	3.321E+00 0.	0.	3.110E-02	.0000	-.0000	-.0000	180.0000	8.0 1.00
4	4.000 3.000	3.538E-01	2.218E+00 6.448E-02	2.335E-02 4.902E-05	1.477E+00 6.170E-02	2.558E-03 1.677E-03	3.973E+00 0.	0.	3.404E-02	.0000	-.0000	-.0000	180.0000	9.0 1.00
3	3.000 2.000	6.939E-01	2.791E+00 1.177E-01	2.586E-02 4.902E-05	1.901E+00 6.170E-02	6.874E-03 1.677E-03	4.655E+00 0.	0.	3.689E-02	.0000	-.0000	-.0000	180.0000	10.0 1.00
2	2.000 1.000	1.320E+00	3.478E+00 2.115E-01	2.845E-02 4.902E-05	2.425E+00 6.170E-02	1.698E-02 1.677E-03	5.493E+00 0.	7.916E-02	3.969E-02	.0000	-.0000	-.0000	180.0000	11.0 1.00
1	1.000 0.000	2.783E+00	4.304E+00 3.671E-01	3.114E-02 4.902E-05	3.070E+00 6.170E-02	3.842E-02 1.677E-03	6.377E+00 0.	2.054E-01	4.249E-02	.0000	-.0000	-.0000	180.0000	12.0 1.00

-6371.230

EQUIVALENT SEA LEVEL ABSORBED AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AER1	OZONE(U-V) ATM CM NITRIC ACID:
W(1-8)=	.238E+01	.430E+01	.311E-01	.307E+01	.384E-01 .367E+00	.638E+01	.205E+00	.425E-01 .490E-04

	AER2	AER3	AER4	P.W. MEAN
W(12-15)=	6.170E-02	1.677E-03	0.	6.671E+01

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EXTINCTION AND ABSORPTION COEFFICIENTS

Table 9. Program Output for Case 4 (Cont.)

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION	NITRIC ACID TRANS
900	11.1111	.6576	.9429	1.0000	1.0000	1.0000	.7114	1.0000	.9808	.0090	.8560	.9995
905	11.0497	.6575	.9379	.9980	1.0000	1.0000	.7164	1.0000	.9808	.0088	2.5686	.9996
910	10.9890	.6598	.9360	.9968	1.0000	1.0000	.7212	1.0000	.9808	.0086	4.2697	.9997
915	10.9290	.6613	.9351	.9947	1.0000	1.0000	.7258	1.0000	.9806	.0085	5.9604	.9998
920	10.8696	.6668	.9388	.9921	1.0000	1.0000	.7303	1.0000	.9804	.0083	7.6263	.9999
925	10.8108	.6842	.9626	.9870	1.0000	1.0000	.7347	1.0000	.9802	.0082	9.2051	1.0000
930	10.7527	.6869	.9660	.9820	1.0000	1.0000	.7389	1.0000	.9801	.0080	10.7704	1.0000
935	10.6952	.6885	.9689	.9763	1.0000	1.0000	.7429	1.0000	.9799	.0079	12.3276	1.0000
940	10.6383	.6854	.9638	.9721	1.0000	1.0000	.7468	1.0000	.9797	.0077	13.9064	1.0000
945	10.5820	.6778	.9519	.9685	.9999	1.0000	.7506	1.0000	.9795	.0076	15.5116	1.0000
950	10.5263	.6733	.9445	.9662	.9990	1.0000	.7543	1.0000	.9791	.0076	17.1450	1.0000
955	10.4712	.6714	.9379	.9673	.9977	1.0000	.7578	1.0000	.9787	.0076	18.7880	1.0000
960	10.4167	.6708	.9351	.9668	.9963	1.0000	.7613	1.0000	.9784	.0076	20.4340	1.0000
965	10.3627	.6707	.9341	.9662	.9938	1.0000	.7646	1.0000	.9780	.0076	22.0605	1.0000
970	10.3093	.6669	.9332	.9617	.9908	1.0000	.7678	1.0000	.9776	.0076	23.7461	1.0000
975	10.2564	.6674	.9360	.9617	.9842	1.0000	.7708	1.0000	.9773	.0076	25.4092	1.0000
980	10.2041	.6710	.9453	.9673	.9736	1.0000	.7738	1.0000	.9769	.0076	27.0444	1.0000
985	10.1523	.6801	.9565	.9767	.9599	1.0000	.7767	1.0000	.9766	.0076	28.6437	1.0000
990	10.1010	.6765	.9655	.9858	.9341	1.0000	.7794	1.0000	.9762	.0076	30.2612	1.0000
995	10.0503	.6571	.9506	.9941	.9111	1.0000	.7821	1.0000	.9759	.0076	31.9756	1.0000
1000	10.0000	.6285	.9360	.9971	.8798	1.0000	.7847	1.0000	.9755	.0076	33.6331	1.0000
1005	9.9502	.6059	.9286	.9985	.8515	1.0000	.7872	1.0000	.9749	.0078	35.8037	1.0000
1010	9.9010	.5820	.9187	.9981	.8252	1.0000	.7896	1.0000	.9742	.0081	37.8937	1.0000
1015	9.8522	.5538	.9051	.9963	.7966	1.0000	.7919	1.0000	.9736	.0084	40.1246	1.0000
1020	9.8039	.5444	.9152	.9937	.7748	1.0000	.7941	1.0000	.9730	.0087	42.4025	1.0000
1025	9.7561	.5369	.9130	.9867	.7683	1.0000	.7962	1.0000	.9723	.0089	44.7178	1.0000
1030	9.7087	.5330	.9164	.9842	.7618	1.0000	.7983	1.0000	.9717	.0092	47.0529	1.0000
1035	9.6618	.4911	.9251	.9767	.6993	1.0000	.8003	1.0000	.9711	.0095	49.5974	1.0000
1040	9.6154	.5091	.9295	.9709	.7246	1.0000	.8022	1.0000	.9705	.0097	52.0519	1.0000
1045	9.5694	.5751	.9313	.9617	.8277	1.0000	.8041	1.0000	.9699	.0100	54.1613	1.0000
1050	9.5238	.5126	.9251	.9587	.7399	1.0000	.8059	1.0000	.9693	.0102	56.5984	1.0000
1055	9.4787	.4925	.9198	.9554	.7165	1.0000	.8076	1.0000	.9688	.0105	59.1353	1.0000
1060	9.4340	.5091	.9062	.9547	.7510	1.0000	.8092	1.0000	.9682	.0107	61.5960	1.0000
1065	9.3897	.5704	.9006	.9528	.7997	1.0000	.8108	1.0000	.9676	.0110	63.8982	1.0000
1070	9.3458	.5331	.9073	.9478	.8734	1.0000	.8124	1.0000	.9670	.0112	65.9476	1.0000
1075	9.3023	.6597	.9095	.9471	.9736	1.0000	.8139	1.0000	.9665	.0115	67.6495	1.0000
1080	9.2593	.6821	.9242	.9521	.9842	1.0000	.8153	1.0000	.9659	.0117	69.2392	1.0000
1085	9.2166	.6928	.9242	.9651	.9853	1.0000	.8167	1.0000	.9654	.0119	70.7750	1.0000
1090	9.1743	.6943	.9152	.9747	.9859	1.0000	.8180	1.0000	.9650	.0119	72.3[illegible]37	1.0000
1095	9.1324	.6931	.9017	.9865	.9859	1.0000	.8192	1.0000	.9646	.0117	73.8381	1.0000
1100	9.0909	.6821	.8795	.9939	.9863	1.0000	.8205	1.0000	.9643	.0116	75.4275	1.0000
1105	9.0498	.5711	.8609	.9982	.9859	1.0000	.8217	1.0000	.9640	.0114	77.0721	1.0000
1110	9.0090	.6678	.8556	.9991	.9853	1.0000	.8228	1.0000	.9636	.0112	78.7331	1.0000
1115	8.9686	.6775	.8671	.9996	.9846	1.0000	.8239	1.0000	.9636	.0112	80.3456	1.0000
1120	8.9286	.5874	.8795	.9990	.9842	1.0000	.8249	1.0000	.9637	.0111	81.9086	1.0000
1125	8.8889	.6985	.8941	.9975	.9839	1.0000	.8260	1.0000	.9637	.0111	83.4164	1.0000
1130	8.8496	.7364	.9051	.9951	.9842	1.0000	.8269	1.0000	.9638	.0111	84.8842	1.0000
1135	8.8106	.6949	.8915	.9909	.9859	1.0000	.8279	1.0000	.9638	.0111	86.4096	1.0000
1140	8.7719	.6864	.8835	.9830	.9893	1.0000	.8288	1.0000	.9639	.0111	87.9777	1.0000
1145	8.7336	.6789	.8779	.9747	.9920	1.0000	.8296	1.0000	.9639	.0111	88.7604	1.0000

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 88.78AVERAGE TRANSMITTANCE = .6376
2

Case 5. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1}, using the MODEL = 0 option to define a 10-km horizontal path at 0-km altitude, at a pressure of 1000 mb, an ambient temperature of $10^{o}C$, and a relative humidity of 40 percent. Use the midlatitude winter ozone profile, and a 23-km meteorological range, rural aerosol model.

The output, shown in Table 10, is similar to the horizontal path case, Case 3, given in Table 4.

Case 6. Calculate, using the MODEL = 7 option, for a given set of radiosonde data the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a slant path from 0.21 km to 8.55 km at a zenith angle of 35.5^{o}. Use a 23-km sea-level meteorological range for the maritime aerosol model and the ozone distribution of the midlatitude summer atmospheric model.

In this example, the radiosonde data consists of 21 levels with the following parameters given: altitude (km), pressure (mb), ambient temperature (^{o}C) and dew-point temperature (^{o}C).

The output for Case 6 is given in Table 11. The only change in the output from a standard run occurs of the first page of the output. Each MODEL = 7 input card is printed followed by the internal model profile parameters derived from this card. Also, detailed information on the aerosol profile and type of extinction is printed for each level. The rest of the output is the same as that described for the previous standard transmittance cases.

Case 7. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a vertical path from ground to 10 km (zenith angle = 0^{o}). Using the MODEL = 7 option, provide for a radiation fog (0.5 km meteorological range) from ground to 200 meters altitude and a rural aerosol model (23-km meteorological range) from 200 meters to 2-km altitude. Use the U.S. Standard model atmosphere profile for the molecular absorber amounts and for the pressure and temperature profile.

In this example, only the altitudes of the levels and the aerosol control parameters need to be specified on the MODEL = 7 cards. The program output for this case is given in Table 12 and is similar to that of Case 6.

Table 10. Program Output for Case 5

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
0 1 1  0  0  0  0  0  3  0  0       0.000      0.000  0  0       0.000
        INPUT METEOROLOGICAL DATA\
        Z=   0.00 KM, P=1000.00 MB,T= 10.0 C, DEW PT.TEMP  0.0 C, REL HUMIDITY= 40.0 %, H2O DENSITY= 0.        GM M-3
         OZONE DENSITY= 0.          GM M-3,  RANGE=     10.000 KM
   0.000  1000.000     10.000  0.0 40.0 C.          0.          0.            0.000  0  0  0:
   0.000  1000.000    283.150  0.0 40.0  .378E+01  .600E-04  .158E+00    23.000  1  1  1  1    RURAL                        RURAL
 900.000  1145.000      5.000

        HORIZONTAL PATH, ALTITUDE =  0.000 KM,RANGE = 10.000 KM

                  HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

                HAZE MODEL  1 =     RURAL       VIS= 23.0KM

               SEASON =    SPRIG SUMM

               VERTICAL PROFILE AEROSOL MODEL =        STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   ( 8.73 - 11.11 MICRONS )


        HORIZONTAL PROFILES

IC      ALT      P         T         H2O       CO2+       O3        N2      H2O(10M)    HCLS     (N-1)     O3(UV)
 1      0.00 1000.000  283.150  7.651E-01 9.305E-01 2.766E-03 7.387E-01 3.181E-03 9.523E-01 0.        2.600E-03



        HORIZONTAL PROFILES
IC      ALT      P         T      H2O(4M)      HNO3      AER1       AER2      AER3      AER4   (AER1*RH)     RH!
 1      0.00 1000.000  283.150  5.714E-02 0.          1.5-3E-01 0.        0.        0.         6.320E+00 4.000E+01

FROM POINT\ HEIGHT=     0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X= 0.          0.        ,IP=  1
          EQUIV. ABSORBER AMOUNTS PER KM AT X=  .368E+00  .930E+00  .277E-02  .739E+00  .316E-02  .952E+00  .156E+00  .281E-02

    TX(12-14)= 0.         0.         ?.?

        EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                     WATER VAPOUR      CO2 ETC.       OZONE     NITROGEN (CONT)  H2O  (CONT)     HCL   SCAT       AER1          OZONE(U-V)
                      GM CM-2           KM          ATM CM          KM          GM CM-2          KM                                  ATM CM
                                                                                                                              NITRIC ACID!

        W(1-8)=       .368E+01       .930E+01      .277E-01      .739E+01      .318E-01      .952E+01     .159E+01      .281E-01
                                                                                .571E+00                                   C

                             AER2          AER3          AER4        R.H. MEAN
        W(12-15)=     0.            0.            0.            4.000E+01

ICH      1    6   10   15
EXTINCTION AND ABSORPTION COEFFICIENTS
```

Table 10. Program Output for Case 5 (Cont.)

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION	NITRIC ACID TRANS
900	11.1111	.6225	.9261	1.0000	1.0000	1.0000	.7544	1.0000	.8910	.0408	.9436	1.0000
905	11.0497	.6194	.9208	.9961	1.0000	1.0000	.7587	1.0000	.8901	.0410	2.8467	1.0000
910	10.9890	.6195	.9188	.9942	1.0000	1.0000	.7629	1.0000	.8891	.0414	4.7486	1.0000
915	10.9290	.6189	.9176	.9907	1.0000	1.0000	.7670	1.0000	.8879	.0426	6.6544	1.0000
920	10.8696	.6207	.9217	.9852	1.0000	1.0000	.7709	1.0000	.8866	.0438	8.5509	1.0000
925	10.8108	.6380	.9507	.9784	1.0000	1.0000	.7747	1.0000	.8854	.0450	10.3608	1.0000
930	10.7527	.6375	.9546	.9703	1.0000	1.0000	.7784	1.0000	.8842	.0462	12.1733	1.0000
935	10.6952	.6351	.9579	.9603	1.0000	1.0000	.7819	1.0000	.8830	.0473	13.9980	1.0000
940	10.6383	.6284	.9520	.9531	1.0000	1.0000	.7853	1.0000	.8819	.0484	15.8562	1.0000
945	10.5820	.6166	.9371	.9475	.9999	1.0000	.7886	1.0000	.8807	.0496	17.7734	1.0000
950	10.5263	.6095	.9278	.9443	.9991	1.0000	.7918	1.0000	.8792	.0507	19.7259	1.0000
955	10.4712	.6066	.9208	.9459	.9980	1.0000	.7949	1.0000	.8779	.0518	21.6929	1.0000
960	10.4167	.6045	.9176	.9451	.9966	1.0000	.7979	1.0000	.8765	.0529	23.6705	1.0000
965	10.3627	.6031	.9165	.9443	.9944	1.0000	.8007	1.0000	.8751	.0540	25.6545	1.0000
970	10.3093	.5973	.9154	.9377	.9911	1.0000	.8035	1.0000	.8738	.0551	27.6685	1.0000
975	10.2564	.5975	.9188	.9377	.9860	1.0000	.8062	1.0000	.8725	.0562	29.6810	1.0000
980	10.2041	.6042	.9287	.9459	.9762	1.0000	.8087	1.0000	.8712	.0573	31.66[illegible]	1.0000
985	10.1523	.6163	.9430	.9608	.9639	1.0000	.8112	1.0000	.8699	.0583	33.5785	1.0000
990	10.1010	.6191	.9539	.9765	.9405	1.0000	.8136	1.0000	.8686	.0594	35.4829	1.0000
995	10.0503	.6011	.9352	.9891	.9184	1.0000	.8159	1.0000	.8673	.0604	37.4772	1.0000
1000	10.0000	.5757	.9188	.9945	.8892	1.0000	.8181	1.0000	.8661	.0614	39.5987	1.0000
1005	9.9502	.5543	.9097	.9970	.8631	1.0000	.8203	1.0000	.8629	.0651	41.6284	1.0000
1010	9.9010	.5294	.8969	.9963	.8379	1.0000	.8223	1.0000	.8598	.0688	44.1615	1.0000
1015	9.8522	.5016	.8810	.9932	.8119	1.0000	.8243	1.0000	.8567	.0725	46.6726	1.0000
1020	9.8039	.4923	.8929	.9881	.7909	1.0000	.8262	1.0000	.8537	.0760	49.2113	1.0000
1025	9.7561	.4827	.8903	.9807	.7848	1.0000	.8281	1.0000	.8507	.0796	51.7978	1.0000
1030	9.7087	.4770	.8942	.9738	.7785	1.0000	.8299	1.0000	.8478	.0831	54.4128	1.0000
1035	9.6618	.4408	.9052	.9608	.7213	1.0000	.8316	1.0000	.8449	.0865	57.2088	1.0000
1040	9.6154	.4523	.9108	.9511	.7442	1.0000	.8332	1.0000	.8420	.0899	59.9472	1.0000
1045	9.5694	.5041	.9131	.9377	.8404	1.0000	.8348	1.0000	.8392	.0932	62.4266	.0000
1050	9.5238	.4484	.9052	.9331	.7590	1.0000	.8364	1.0000	.8364	.0967	65.1844	[illegible]
1055	9.4787	.4291	.8982	.9285	.7367	1.0000	.8378	1.0000	.8336	.1000	68.0389	[illegible]
1060	9.4340	.4388	.8824	.9276	.7688	1.0000	.8393	1.0000	.8309	.1032	70.9447	[illegible]
1065	9.3897	.4592	.8750	.9250	.8149	1.0000	.8406	1.0000	.8282	.1064	73.5488	[illegible]
1070	9.3458	.4985	.8837	.9185	.8837	1.0000	.8420	1.0000	.8256	.1095	76.0559	[illegible]
1075	9.3023	.5508	.8863	.9173	.9762	1.0000	.8432	1.0000	.8229	.1126	78.3020	[illegible]
1080	9.2593	.5707	.9041	.9241	.9860	1.0000	.8445	1.0000	.8204	.1157	80.4487	1.0000
1085	9.2166	.5818	.9041	.9428	.9870	1.0000	.8456	1.0000	.8178	.1187	82.5397	1.0000
1090	9.1743	.5647	.8929	.9577	.9877	1.0000	.8468	1.0000	.8170	.1185	84.6182	1.0000
1095	9.1324	.5869	.8766	.9776	.9877	1.0000	.8479	1.0000	.8173	.1161	86.6855	1.0000
1100	9.0909	.5753	.8487	.9886	.9888	1.0000	.8489	1.0000	.8176	.1138	88.8[illegible]87	1.0000
1105	9.0498	.5651	.8259	.9964	.9877	1.0000	.8499	1.0000	.8179	.1115	90.9834	1.0000
1110	9.0090	.5625	.8200	.9983	.9870	1.0000	.8509	1.0000	.8182	.1092	93.1768	1.0000
1115	8.9686	.5737	.8338	.9992	.9863	1.0000	.8518	1.0000	.8190	.1078	95.3045	1.0000
1120	8.9286	.5839	.8487	.9981	.9860	1.0000	.8527	1.0000	.8199	.1068	97.3850	1.0000
1125	8.8889	.5950	.8673	.9952	.9857	1.0000	.8536	1.0000	.8208	.1058	99.4049	1.0000
1130	8.8496	.6043	.8810	.9910	.9868	1.0000	.8544	1.0000	.8216	.1048	101.3832	1.0000
1135	8.8106	.5904	.8542	.9833	.9877	1.0000	.8552	1.0000	.8225	.1038	103.4312	1.0000
1140	8.7719	.5796	.8541	.9719	.9907	1.0000	.8560	1.0000	.8234	.1028	105.5335	1.0000
1145	8.7336	.5686	.8469	.9577	.9929	1.0000	.8568	1.0000	.8242	.1019	106.6119	1.0000

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 106.61AVERAGE TRANSMITTANCE = .5648
?

Table 11. Program Output for Case 5

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
7  3  2  0  0  1  0  0  2 21  0      0.000      0.000  0  0       0.000
MODEL ATMOSPHERE NO. 7
 Z (KM)    P (MB)     T (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.                                    AEROSOL PROFILE      EXTINCTION
  0.000   1015.000     24.400 21.4  0.0 0.         0.         0.          0.000  0  0  0:
  0.000   1015.000    297.550 21.4  0.0  .186E+02  .600E-04  .158E+00    23.000  3  1  1  3  MARITIME                         MARITIME
   .136   1000.000     22.000 19.4  0.0 0.         0.         0.          0.000  0  0  0:
   .136   1000.000    295.150 19.4  0.0  .165E+02  .600E-04  .148E+00    23.000  3  1  1  3  MARITIME                         MARITIME
   .560    950.000     17.800 16.1  0.0 0.         0.         0.          0.000  0  0  0:
   .560    950.000    290.950 16.1  0.0  .136E+02  .600E-04  .122E+00    23.000  3  1  1  3  MARITIME                         MARITIME
  1.080    892.000     14.600 11.9  0.0 0.         0.         0.          0.000  0  0  0:
  1.080    892.000    287.950 11.9  0.0  .105E+02  .600E-04  .955E-01    23.000  3  1  1  3  MARITIME                         MARITIME
  1.526    850.000     12.800  5.8  0.0 0.         0.         0.          0.000  0  0  0:
  1.526    850.000    285.950  5.8  0.0  .599E+01  .600E-04  .775E-01    23.000  3  1  1  3  MARITIME                         MARITIME
  1.650    832.000     12.800 -6.2  0.0 0.         0.         0.          0.000  0  0  0:
  1.650    832.000    285.950 -6.2  0.0  .292E+01  .600E-04  .731E-01    23.000  3  1  1  3  MARITIME                         MARITIME
  2.270    775.000     11.200-18.2  0.0 0.         0.         0.          0.000  0  0  0:
  2.270    775.000    284.350-18.2  0.0  .111E+01  .605E-04  .530E-01    23.000  3  1  1  6            SPRIG SUMM             TROPOSPHER
  3.140    700.000      7.200-20.8  0.0 0.         0.         0.          0.000  0  0  0:
  3.140    700.000    280.350-20.6  0.0  .905E+00  .623E-04  .317E-01    23.000  3  1  1  6            SPRIG SUMM             TROPOSPHER
  5.820    500.000    -10.100-28.1  0.0 0.         0.         0.          0.000  0  0  0:
  5.820    500.000    263.050-28.1  0.0  .501E+00  .685E-04  .798E-02    23.000  3  1  1  6            SPRIG SUMM             TROPOSPHER
  5.990    488.000    -11.500-27.5  0.0 0.         0.         0.          0.000  0  0  0:
  5.990    488.000    261.650-27.5  0.0  .533E+00  .694E-04  .772E-02    23.000  3  1  1  6            SPRIG SUMM             TROPOSPHER
  7.510    400.000    -19.500-31.5  0.0 0.         0.         0.          0.000  0  0  0:
  7.510    400.000    254.650-31.5  0.0  .377E+00  .770E-04  .455E-02    23.000  3  1  1  6            SPRIG SUMM             TROPOSPHER
  8.720    338.000    -28.500-41.5  0.0 0.         0.         0.          0.000  0  0  0:
  8.720    338.000    244.650-41.5  0.0  .143E+00  .840E-04  .216E-02    23.000  3  1  1  6            SPRIG SUMM             TROPOSPHER
  9.130    318.000    -32.700-39.7  0.0 0.         0.         0.          0.000  0  0  0:
  9.130    318.000    240.450-39.7  0.0  .176E+00  .867E-04  .167E-02    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
  9.590    300.000    -35.300-43.3  0.0 0.         0.         0.          0.000  0  0  0:
  9.590    300.000    237.850-43.3  0.0  .122E+00  .683E-04  .138E-02    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
  9.720    294.000    -34.700-42.7  0.0 0.         0.         0.          0.000  0  0  0:
  9.720    294.000    238.450-42.7  0.0  .129E+00  .889E-04  .130E-02    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
 10.020    281.000    -38.700-45.7  0.0 0.         0.         0.          0.000  0  0  0:
 10.020    281.000    234.450-45.7  0.0  .951E-01  .904E-04  .113E-02    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
 10.830    250.000    -44.700-50.0  0.0 0.         0.         0.          0.000  0  0  0:
 10.830    250.000    228.450-50.0  0.0  .502E-01  .106E-03  .849E-03    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
 12.290    200.000    -57.100-50.0  0.0 0.         0.         0.          0.000  0  0  0:
 12.290    200.000    216.050-50.0  0.0  .636E-01  .126E-03  .602E-03    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
 13.610    161.000    -69.500-50.0  0.0 0.         0.         0.          0.000  0  0  0:
 13.610    161.000    203.650-50.0  0.0  .675E-01  .167E-03  .471E-03    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
 14.050    150.000    -71.100-50.0  0.0 0.         0.         0.          0.000  0  0  0:
 14.050    150.000    202.050-50.0  0.0  .581E-01  .180E-03  .440E-03    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
 15.450    130.000    -70.900-50.0  0.0 0.         0.         0.          0.000  0  0  0:
 16.450    120.000    202.250-50.0  0.0  .580E-01  .223E-03  .401E-03    23.000  3  1  1 10            SPRIG SUMM STRAT BKGR  BACK STRA
           .210       8.550     35.500      0.000      0.000
       H1=    .210KM,H2=   8.550KM,ANGLE= 35.500GEOM. RANGE =  10.24KM,BETA=   .05341
900.000  1145.000       5.000


        SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =    .210 KM H2 =   8.550 KM,ZENITH ANGLE = 35.000 DEGREES

                  HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

                 HAZE MODEL  3 =  MARITIME      VIS= 23.0KM

               SEASON =    SPRIG SUMM

               VERTICAL PROFILE AEROSOL MODEL =        STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =    5.0 CM-1   ( 8.73 - 11.11 MICRONS )
```

Table 11. Program Output for Case 6 (Cont.)

HORIZONTAL PROFILES

ID	ALT	P	T	H2O	CO2+	O3	N2	H2O(10M)	MOLS	(N-1)	O3(UV)
1	0.00	1015.000	297.550	1.789E+00	8.921E-01	2.755E-03	7.064E-01	4.891E-02	9.198E-01	2.623E-04	2.800E-03
2	.14	1000.000	295.150	1.579E+00	8.789E-01	2.743E-03	6.941E-01	4.064E-02	9.136E-01	2.568E-04	2.800E-03
3	.56	950.000	290.950	1.250E+00	8.194E-01	2.695E-03	6.400E-01	2.987E-02	8.804E-01	2.458E-04	2.800E-03
4	1.08	892.000	287.950	9.125E-01	7.444E-01	2.633E-03	5.735E-01	1.891E-02	8.353E-01	2.346E-04	2.800E-03
5	1.53	850.000	285.950	5.844E-01	6.907E-01	2.586E-03	5.259E-01	9.039E-03	8.015E-01	2.275E-04	2.800E-03
6	1.65	832.000	285.950	2.397E-01	6.654E-01	2.564E-03	5.038E-01	1.850E-03	7.846E-01	2.179E-04	2.800E-03
7	2.27	775.000	284.950	5.585E-02	5.905E-01	2.517E-03	4.395E-01	3.740E-04	7.334E-01	2.020E-04	2.825E-03
8	3.14	700.000	280.350	6.416E-02	5.053E-01	2.494E-03	3.674E-01	2.721E-04	6.733E-01	1.703E-04	2.906E-03
9	5.82	500.000	263.050	2.700E-02	3.061E-01	2.427E-03	2.062E-01	1.139E-04	5.125E-01	1.458E-04	3.194E-03
10	5.99	485.000	261.650	2.914E-02	2.955E-01	2.424E-03	1.980E-01	1.264E-04	5.029E-01	1.333E-04	3.219E-03
11	7.51	400.000	253.650	1.590E-02	2.178E-01	2.515E-03	1.354E-01	7.518E-05	4.252E-01	1.146E-04	3.594E-03
12	8.72	338.000	244.650	5.505E-03	1.704E-01	2.583E-03	1.051E-01	1.775E-05	3.725E-01	1.047E-04	3.919E-03
13	9.18	316.000	241.450	6.564E-03	1.569E-01	2.611E-03	9.545E-02	2.484E-05	3.566E-01	1.001E-04	4.046E-03
14	9.59	300.000	237.650	4.329E-03	1.438E-01	2.605E-03	8.635E-02	1.429E-05	3.401E-01	9.660E-05	4.122E-03
15	9.72	294.000	238.450	4.916E-03	1.383E-01	2.598E-03	8.262E-02	1.540E-05	3.325E-01	9.417E-05	4.147E-03
16	10.02	281.000	234.450	3.211E-03	1.308E-01	2.603E-03	7.741E-02	1.004E-05	3.232E-01	8.881E-05	4.217E-03
17	10.63	250.000	228.450	1.852E-03	1.105E-01	2.938E-03	6.370E-02	5.248E-06	2.951E-01	7.824E-05	4.961E-03
18	12.29	200.000	216.050	1.642E-03	8.073E-02	3.272E-03	4.433E-02	6.290E-06	2.496E-01	6.647E-05	5.574E-03
19	13.60	161.000	203.650	1.472E-03	5.991E-02	3.968E-03	3.139E-02	8.815E-06	2.132E-01	5.937E-05	7.809E-03
20	14.05	150.000	202.050	1.397E-03	5.350E-02	4.167E-03	2.757E-02	9.224E-[illegible]	2.002E-01	4.250E-05	8.423E-03
21	16.45	100.000	202.250	9.685E-04	3.628E-02	4.377E-03	1.224E-02	8.481E-06	1.333E-01	0.	1.041E-02

HORIZONTAL PROFILES

ID	ALT	P	T	H2O(4M)	HNO3	AER1	AER2	AER3	AER4	(AER1*RH)	RH%
1	0.00	1015.000	297.550	2.581E-01	0.	1.580E-01	0.	0.	0.	1.310E+01	8.294E+01
2	.14	1000.000	295.150	2.313E-01	0.	1.483E-01	0.	0.	0.	1.258E+01	8.484E+01
3	.56	950.000	290.950	1.594E-01	0.	1.217E-01	0.	0.	0.	1.090E+01	8.957E+01
4	1.08	892.000	287.950	1.402E-01	0.	9.546E-02	0.	0.	0.	7.874E+00	8.246E+01
5	1.53	850.000	285.950	8.314E-02	0.	7.750E-02	0.	0.	0.	4.834E+00	6.198E+01
6	1.65	832.000	285.950	3.489E-02	0.	7.314E-02	0.	0.	0.	1.880E+00	2.571E+01
7	2.27	775.000	284.950	1.237E-02	0.	0.	5.303E-02	0.	0.	0.	0.
8	3.14	700.000	280.350	9.803E-03	0.	0.	3.170E-02	0.	0.	0.	0.
9	5.82	500.000	263.050	5.302E-03	0.	0.	7.976E-03	0.	0.	0.	0.
10	5.99	485.000	261.650	5.657E-03	0.	0.	7.725E-03	0.	0.	0.	0.
11	7.51	400.000	253.650	3.358E-03	0.	0.	4.554E-03	0.	0.	0.	0.
12	8.72	338.000	244.650	1.495E-03	7.098E-20	0.	2.163E-03	0.	0.	0.	0.
13	9.18	318.000	240.450	1.908E-03	4.421E-06	0.	0.	1.673E-03	0.	0.	0.
14	9.59	300.000	237.650	1.322E-03	6.879E-06	0.	0.	1.381E-03	0.	0.	0.
15	9.72	294.000	238.450	1.359E-03	7.854E-06	0.	0.	1.300E-03	0.	0.	0.
16	10.02	281.000	234.450	1.051E-03	1.086E-05	0.	0.	1.132E-03	0.	0.	0.
17	10.83	250.000	228.450	6.877E-04	2.031E-05	0.	0.	8.488E-04	0.	0.	0.
18	12.29	200.000	216.050	8.170E-04	3.132E-05	0.	0.	6.023E-04	0.	0.	0.
19	13.60	161.000	203.650	1.021E-03	3.233E-05	0.	0.	4.706E-04	0.	0.	0.
20	14.05	150.000	202.050	1.011E-03	3.222E-05	0.	0.	4.395E-04	0.	0.	0.
21	16.45	100.000	202.250	6.599E-04	2.592E-05	0.	0.	4.008E-04	0.	0.	0.

FROM POINT\ HEIGHT= .2100 KM,N= 2,NP= 0,REF. INDEX ABOVE & BELOW X= .2560E-03 .2607E-03,IP= 1
EQUIV. ABSORBER AMOUNTS PER KM AT X= .152E+01 .868E+00 .273E-02 .684E+00 .385E-01 .908E+00 .143E+00 .280E-02

TX(12-14)= 0. 0. 0.1

FROM POINT\ HEIGHT= 8.5500 KM,N= 11,NP= 0,REF. INDEX ABOVE & BELOW X= .1080E-03 .1156E-03,IP= 1
EQUIV. ABSORBER AMOUNTS PER KM AT X= .654E-02 .176E+00 .257E-02 .109E+00 .217E-04 .386E+00 0. .387E-02

TX(12-14)= .240E-02 0. 0.1

Table 11. Program Output for Case 6 (Cont.)

VERTICAL PROFILES

IC	ALT	H2O	CO2+ H2O(4M)	O2 HNO3	N2 AER2	H2O(10M) AER3	MOLS AER4	AER1	O3(UV)	PSI	PHI	BETA	THETA	RANGE ORANGE
2	.210 .560	5.926E-01	3.627E-01 6.852E-02	1.167E-03 0.	2.846E-01 0.	1.462E-02 0.	3.847E-01 0.	5.682E-02	1.204E-03	0.0003	144.5022	.0022	35.5[illegible]	.4 .43
3	.560 1.080	1.278E+00	8.617E-01 1.930E-01	2.868E-03 0.	6.716E-01 0.	2.993E-02 0.	5.321E-01 0.	1.258E-01	2.992E-03	.0004	144.5052	.0058	35.4982	1.1 .64
4	1.080 1.526	1.681E+00	1.255E+00 2.548E-01	4.298E-03 0.	3.724E-01 0.	3.726E-02 0.	1.380E+00 0.	1.730E-01	4.526E-03	.0009	144.5076	.0084	35.4953	1.6 .55
5	1.526 1.650	1.740E+00	1.758E+00 2.636E-01	4.690E-03 0.	1.051E+00 0.	3.795E-02 0.	1.501E+00 0.	1.845E-01	4.952E-03	.0012	144.5081	.0092	35.4927	1.8 .15
6	1.650 2.270	1.854E+00	1.835E+00 2.831E-01	5.625E-03 0.	1.409E+00 0.	3.655E-02 0.	2.079E+00 0.	1.845E-01	7.094E-03	.0016	144.5117	.0132	35.4923	2.5 .76
7	2.270 3.140	1.933E+00	2.420E+00 2.919E-01	9.301E-03 0.	1.639E+00 4.429E-02	3.699E-02 0.	2.850E+00 0.	1.845E-01	1.016E-02	.0022	144.5166	.0188	35.4890	3.6 1.67
8	3.140 5.820	2.075E+00	3.728E+00 3.[illegible]69E-01	1.740E-02 0.	2.758E+00 1.009E-01	3.959E-02 0.	4.769E+00 0.	1.845E-01	2.019E-02	.0035	144.5324	.0359	35.4847	6.9 3.29
9	5.820 5.990	2.080E+00	3.790E+00 3.171E-01	1.790E-02 0.	2.800E+00 1.025E-01	3.962E-02 0.	4.875E+00 0.	1.845E-01	2.[illegible]86E-02	.0045	144.5325	.0370	35.4686	7.1 .21
10	5.990 7.510	2.122E+00	4.266E+00 3.259E-01	2.251E-02 0.	3.112E+00 1.137E-01	3.960E-02 0.	5.739E+00 0.	1.845E-01	2.721E-02	.0050	144.5418	.0468	35.4660	9.0 1.87
11	7.510 8.550	2.135E+00	4.516E+00 3.293E-01	2.576E-02 0.	3.270E+00 1.180E-01	3.985E-02 0.	6.252E+00 0.	1.845E-01	3.197E-02	.0057	144.5477	.0534	35.4590	10.2 1.28

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AER1	OZONE(U-V) ATM CM NITRIC ACID
W(1-8)=	.214E+01	.452E+01	.250E-01	.327E+01	.799E-01 .329E+00	.625E+01	.134E+00	.320E-01

	AER2	AER3	AER4	R.H. MEAN
W(12-15)=	1.180E-01	0.	0.	8.019E+01

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EXTINCTION AND ABSORPTION COEFFICIENTS

Table 11. Program Output for Case 6 (Cont.)

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION	NITRIC ACID TRANS
900	11.1111	.6451	.9466	1.0000	1.0000	1.0000	.7025	1.0000	.9701	.0204	.8872	1.0000
905	11.0497	.6454	.9419	.9979	1.0000	1.0000	.7075	1.0000	.9744	.0198	2.6641	1.0000
910	10.9890	.6482	.9404	.9967	1.0000	1.0000	.7125	1.0000	.9707	.0193	4.4191	1.0000
915	10.9290	.6505	.9395	.9945	1.0000	1.0000	.7172	1.0000	.9747	.0188	6.1667	1.0000
920	10.8696	.6551	.9427	.9918	1.0000	1.0000	.7218	1.0000	.9707	.0183	7.8513	1.0000
925	10.8108	.6713	.9653	.9865	1.0000	1.0000	.7263	1.0000	.9706	.0178	9.5347	1.0000
930	10.7527	.6742	.9687	.9815	1.0000	1.0000	.7306	1.0000	.9706	.0174	11.1636	1.0000
935	10.6952	.6755	.9711	.9755	1.0000	1.0000	.7347	1.0000	.9706	.0165	12.7851	1.0000
940	10.6383	.6730	.9665	.9712	1.0000	1.0000	.7388	1.0000	.9706	.0164	14.4210	1.0000
945	10.5820	.6658	.9550	.9673	.9999	1.0000	.7427	1.0000	.9705	.0160	16.0922	1.0000
950	10.5263	.6620	.9482	.9650	.9992	1.0000	.7464	1.0000	.9700	.0159	17.7622	1.0000
955	10.4712	.6605	.9419	.9662	.9981	1.0000	.7501	1.0000	.9696	.0158	19.4792	1.0000
960	10.4167	.6604	.9395	.9656	.9969	1.0000	.7536	1.0000	.9691	.0157	21.1770	1.0000
965	10.3627	.6607	.9386	.9650	.9948	1.0000	.7570	1.0000	.9687	.0155	22.8734	1.0000
970	10.3093	.6574	.9377	.9605	.9917	1.0000	.7602	1.0000	.9683	.0154	24.5863	1.0000
975	10.2564	.6587	.9404	.9605	.9870	1.0000	.7634	1.0000	.9678	.0153	26.2930	1.0000
980	10.2041	.6647	.9490	.9662	.9778	1.0000	.7664	1.0000	.9674	.0152	27.9694	1.0000
985	10.1523	.6732	.9596	.9759	.9663	1.0000	.7694	1.0000	.9670	.0151	29.6034	1.0000
990	10.1010	.6719	.9682	.9853	.9437	1.0000	.7722	1.0000	.9665	.0149	31.2437	1.0000
995	10.0503	.6555	.9537	.9939	.9236	1.0000	.7750	1.0000	.9661	.0148	32.9663	1.0000
1000	10.0000	.6293	.9404	.9969	.8948	1.0000	.7776	1.0000	.9657	.0147	34.8166	1.0000
1005	9.9502	.6093	.9330	.9984	.8697	1.0000	.7802	1.0000	.9650	.0149	36.7671	1.0000
1010	9.9010	.5876	.9231	.9981	.8452	1.0000	.7826	1.0000	.9643	.0152	38.8285	1.0000
1015	9.8522	.5631	.9104	.9962	.8208	1.0000	.7850	1.0000	.9635	.0154	41.0135	1.0000
1020	9.8039	.5546	.9205	.9934	.8004	1.0000	.7873	1.0000	.9628	.0156	43.2394	1.0000
1025	9.7561	.5475	.9184	.9882	.7943	1.0000	.7895	1.0000	.9621	.0158	45.5117	1.0000
1030	9.7087	.5436	.9214	.9837	.7841	1.0000	.7916	1.0000	.9614	.0161	47.7835	1.0000
1035	9.6619	.5170	.9293	.9759	.7332	1.0000	.7937	1.0000	.9607	.0163	50.2487	1.0000
1040	9.6154	.5229	.9339	.9701	.7556	1.0000	.7957	1.0000	.9600	.0165	52.6341	1.0000
1045	9.5694	.5828	.9358	.9655	.8475	1.0000	.7976	1.0000	.9594	.0167	54.7260	1.0000
1050	9.5238	.5243	.9293	.9573	.7691	1.0000	.7994	1.0000	.9587	.0169	57.0983	1.0000
1055	9.4787	.5062	.9240	.9540	.7482	1.0000	.8012	1.0000	.9580	.0171	59.5671	1.0000
1060	9.4340	.5282	.9115	.9534	.7780	1.0000	.8029	1.0000	.9574	.0173	61.9660	1.0000
1065	9.3897	.5462	.9059	.9514	.8233	1.0000	.8045	1.0000	.9567	.0175	64.2351	1.0000
1070	9.3458	.5913	.9127	.9462	.8893	1.0000	.8061	1.0000	.9561	.0177	66.2756	1.0000
1075	9.3023	.6527	.9150	.9454	.9778	1.0000	.8076	1.0000	.9554	.0179	68.0123	1.0000
1080	9.2593	.6731	.9284	.9507	.9870	1.0000	.8091	1.0000	.9548	.0181	69.6470	1.0000
1085	9.2166	.6838	.9284	.9639	.9881	1.0000	.8105	1.0000	.9542	.0183	71.2286	1.0000
1090	9.1743	.6864	.9205	.9739	.9888	1.0000	.8119	1.0000	.9538	.0182	72.7960	1.0000
1095	9.1324	.6857	.9070	.9860	.9888	1.0000	.8132	1.0000	.9535	.0180	74.3676	1.0000
1100	9.0909	.6759	.8859	.9937	.9891	1.0000	.8144	1.0000	.9533	.0177	75.9883	1.0000
1105	9.0498	.6661	.8683	.9982	.9888	1.0000	.8157	1.0000	.9530	.0175	77.6575	1.0000
1110	9.0090	.6634	.8636	.9990	.9881	1.0000	.8168	1.0000	.9528	.0172	79.3404	1.0000
1115	8.9686	.6724	.8745	.9996	.9874	1.0000	.8180	1.0000	.9526	.0171	80.9782	1.0000
1120	8.9286	.6813	.8859	.9989	.9870	1.0000	.8190	1.0000	.9524	.0171	82.5716	1.0000
1125	8.8889	.6913	.9003	.9973	.9867	1.0000	.8201	1.0000	.9522	.0170	84.1123	1.0000
1130	8.8496	.6989	.9104	.9949	.9878	1.0000	.8211	1.0000	.9520	.0169	85.6182	1.0000
1135	8.8106	.6880	.8977	.9905	.9886	1.0000	.8221	1.0000	.9519	.0169	87.1782	1.0000
1140	8.7719	.6787	.8698	.9825	.9913	1.0000	.8230	1.0000	.9517	.0168	88.7646	1.0000
1145	8.7336	.6708	.8845	.9739	.9933	1.0000	.8239	1.0000	.9515	.0168	89 6.74	1.0000

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 89 .1AVERAGE TRANSMITTANCE = .6343
2

Table 12. Program Output for Case 7

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PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
7  9  2  9  0  1  6  6  6 12  0      0.000      0.000  0  0      0.000
MODEL ATMOSPHERE NO. 7
  Z (KM)    P (MB)     T (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.                                        AEROSOL PROFILE       EXTINCTION
   0.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
   0.000   1013.000    293.100  0.0  0.0  .590E+01  .540E-04  .749E+01        .500  9  1  1  9 FOG2 (RAD)                            FOG2 (RAD)
    .200      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
    .200    989.010    266.788  0.0  0.0  .551E+01  .540E-04  .749E+01        .500  9  1  1  9 FOG2 (RAD)                            FOG2 (RAD)
    .201      0.000      0.000  0.0  0.0 0.          0.          0.          23.000  1  0  0*
    .201    988.892    266.792  0.0  0.0  .551E+01  .540E-04  .144E+00       23.000  1  1  1  1    RURAL                                RURAL
   1.000      0.000      0.000  0.0  0.0 0.          0.          0.          23.000  1  0  0*
   1.000    896.600    281.600  0.0  0.0  .420E+01  .540E-04  .991E-01       23.000  1  1  1  1    RURAL                                RURAL
   2.000      0.000      0.000  0.0  0.0 0.          0.          0.          23.000  1  0  0*
   2.000    795.000    275.100  0.0  0.0  .290E+01  .540E-04  .621E-01       23.000  1  1  1  1    RURAL                                RURAL
   2.010      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
   2.010    794.193    275.035  0.0  0.0  .289E+01  .540E-04  .617E-01        .500  9  1  1  6             SPRIG SUMM            TROPOSPHER
   5.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
   5.000    540.500    255.700  0.0  0.0  .540E+00  .460E-04  .931E-02        .500  9  1  1  6             SPRIG SUMM            TROPOSPHER
  10.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  10.000    265.000    223.200  0.0  0.0  .180E-01  .900E-04  .114E-02        .500  9  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  11.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  11.000    227.000    216.800  0.0  0.0  .320E-02  .139E-03  .799E-03        .500  9  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  30.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  30.000     11.970    226.500  0.0  0.0  .380E-03  .200E-03  .332E-04        .500  9  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  35.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  35.000      5.746    236.500  0.0  0.0  .160E-03  .110E-03  .164E-04        .500  9  1  1 10                        STRAT BKGR  BACK STRA
  70.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  70.000       .055    219.700  0.0  0.0  .150E-06  .860E-07  .160E-06        .500  9  1  1 10                        STRAT BKGR  BACK STRA
              0.000     10.000       0.000       0.000       0.000
         H1=  0.000KM,H2= 10.000KM,ANGLE=  0.00000FOM. RANGE =  1..00KM,BETA= 0.00000
 900.000  1145.000      5.000

         SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =  0.000 KM H2 = 10.000 KM,ZENITH ANGLE =  0.000 DEGREES

                   HAZE MODEL  =    .5 KM VISUAL RANGE AT SEA LEVEL

                  HAZE MODEL  9 = FOG2 (RAD)     VIS=    .5KM

              SEASON =    SPRIG SUMM

              VERTICAL PROFILE AEROSOL MODEL =       STRAT BKGR

         FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =    5.0 CM-1   ( 8.73 - 11.11 MICRONS )
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Table 12. Program Output for Case 7 (Cont.)

HORIZONTAL PROFILES

ID	ALT	P	T	H2O	CO2*	O3	N2	H2O(10M)	HCLS	(N-1)	O3(UV)
1	0.00	1013.000	288.100	5.760E-01	3.294E-01	[illegible].493E-03	7.385E-01	5.574E-03	9.481E-01	2.594E-04	2.520E-03
2	.20	989.010	286.788	5.278E-01	8.968E-01	2.472E-03	7.086E-01	5.899E-03	9.299E-01	2.668E-04	2.520E-03
3	.20	988.892	286.782	5.275E-01	8.966E-01	2.472E-03	7.087E-01	5.896E-03	9.298E-01	2.569E-04	2.520E-03
4	1.00	898.600	281.600	3.719E-01	7.776E-01	2.387E-03	6.014E-01	3.832E-03	8.604E-01	2.353E-04	2.520E-03
5	2.00	795.000	275.100	2.324E-01	5.480E-01	2.284E-03	4.875E-01	2.127E-03	7.792E-01	2.236E-04	2.520E-03
6	2.01	794.003	275.035	2.311E-01	6.468E-01	2.281E-03	4.864E-01	2.111E-03	7.784E-01	1.936E-04	2.518E-03
7	5.00	540.500	255.700	7.746E-02	3.648E-01	1.692E-03	2.515E-01	1.927E-04	5.700E-01	1.278E-04	2.147E-03
8	10.00	265.000	223.200	5.297E-04	1.263E-01	2.558E-03	7.412E-02	1.181E-06	3.201E-01	8.654E-05	4.200E-03
9	11.00	227.000	216.800	2.768E-04	1.0[illegible]01	3.493E-03	5.681E-02	4.288E-07	2.823E-01	4.260E-05	6.067E-03
10	30.00	11.970	226.500	7.614E-07	5.[illegible]4	1.642E-03	1.479E-04	9.944E-10	1.425E-02	2.988E-06	9.333E-03
11	35.00	5.746	236.500	1.524E-07	1.4[illegible]4	6.674E-04	3.195E-05	1.943E-10	6.551E-03	9.508E-07	5.133E-03
12	70.00	.055	219.700	2.406E-12	4.662E-08	8.259E-08	3.293E-09	1.653E-15	6.775E-05	0.	4.013E-06

HORIZONTAL PROFILES

ID	ALT	P	T	H2O(4M)	HNO3	AER1	AER2	AER3	AER4	(AER1*RH)	RH
1	0.00	1013.000	288.100	8.473E-02	0.	7.495E+00	0.	0.	0.	0.	4.575E+01
2	.20	989.010	286.768	7.882E-02	0.	7.495E+00	0.	0.	0.	0.	4.635E+01
3	.20	988.892	286.762	7.879E-02	0.	0.	1.439E-01	0.	0.	6.669E+00	4.635E+01
4	1.00	898.600	281.600	5.897E-02	0.	0.	9.910E-02	0.	0.	4.862E+00	4.906E+01
5	2.00	795.000	275.100	3.993E-02	0.	0.	6.210E-02	0.	0.	3.238E+00	5.214E+01
6	2.01	794.003	275.035	3.973E-02	0.	0.	0.	6.174E-02	0.	0.	0.
7	5.00	540.500	255.700	8.494E-03	0.	0.	0.	9.310E-03	0.	0.	0.
8	10.00	265.000	223.200	2.502E-04	1.056E-05	0.	0.	0.	1.140E-03	0.	0.
9	11.00	227.000	216.800	1.167E-04	2.259E-05	0.	0.	0.	7.990E-04	0.	0.
10	30.00	11.970	226.500	2.184E-07	3.705E-06	0.	0.	0.	3.320E-05	0.	0.
11	35.00	5.746	236.500	3.471E-08	1.441E-07	0.	0.	0.	1.640E-05	0.	0.
12	70.00	.055	219.700	4.770E-13	0.	0.	0.	0.	1.600E-07	0.	0.

```
FROM POINT\ HEIGHT=    0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X=  .2694E-03 0.        ,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .576E+00  .929E+00  .249E-02  .739E+00  .657E-02  .948E+00  .749E+01  .252E-02

   TX(12-14)= 0.        0.        0.1

FROM POINT\ HEIGHT=   10.0000 KM,N=  8,NP= 1,REF. INDEX ABOVE & BELOW X=  .8654E-04  .1272E-03,IP=  1
        EQUIV  ABSORBER AMOUNTS PER KM AT X=  .590E-03  .126E+00  .256E-02  .741E-01  .118E-05  .320E+00 0.          .420E-02

   TX(12-14)= 0.        0.        .114E-02
```

Table 12. Program Output for Case 7 (Cont.)

VERTICAL PROFILES

IC	ALT	H2O	CO2+ H2O(4M)	O3 HNO3	N2 AER2	H2O(10M) AER3	MOLS AER4	AER1	O3(UV)	PSI	PHI	BETA	THETA	RANGE CHANGE
1	0.000 .200	1.103E-01	1.826E-01 1.635E-02	4.555E-04 0.	1.447E-01 0.	1.246E-03 0.	1.878E-01 0.	1.499E+00	5.040E-04	0.0000	180.0000	0.0000	0.0000	.2 .20
2	.200 .201	1.108E-01	1.875E-01 1.643E-02	4.590E-04 0.	1.454E-01 0.	1.252E-03 0.	1.887E-01 0.	1.499E+00	5.065E-04	0.0000	180.0000	0.0000	0.0000	.2 .00
3	.201 1.000	4.666E-01	8.512E-01 7.108E-02	2.440E-03 0.	6.676E-01 3.595E-02	5.079E-03 0.	9.036E-01 0.	1.499E+00	2.520E-03	0.0000	180.0000	0.0000	0.0000	1.0 .80
4	1.000 2.000	7.633E-01	1.562E+00 1.199E-01	4.775E-03 0.	1.210E+00 1.751E-01	7.976E-03 0.	1.773E+00 0.	1.499E+00	5.040E-03	0.0000	180.0000	0.0000	0.0000	2.0 1.00
5	2.000 2.010	7.656E-01	1.568E+00 1.207E-01	4.799E-03 0.	1.215E+00 1.751E-01	7.997E-03 0.	1.731E+00 0.	1.499E+00	5.065E-03	0.0000	180.0000	0.0000	0.0000	2.0 .01
6	2.010 5.000	1.084E+00	3.041E+00 1.809E-01	1.069E-02 0.	2.280E+00 1.751E-01	1.039E-02 8.286E-02	3.730E+00 0.	1.499E+00	1.202E-02	0.0000	180.0050	0.0000	0.0000	5.0 2.99
7	5.000 10.000	1.128E+00	4.165E+00 1.925E-01	2.117E-02 0.	3.106E+00 1.751E-01	1.158E-02 8.286E-02	5.896E+00 0.	1.499E+00	2.732E-02	0.0000	180.0000	0.0000	0.0000	10.0 5.00

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AER1	OZONE(U-V) ATM CM NITRIC ACID*
W(1-9)=	.113E+01	.416E+01	.212E-01	.701E+01	.106E-01 .193E+00	.590E+01	.150E+01	.273E-01 0.

	AER2	AER3	AER4	R.H. MEAN
W(12-15)=	1.751E-01	8.285E-02	0.	4.890E+01

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EXTINCTION AND ABSORPTION COEFFICIENTS

Table 12. Program Cutput for Case 7 (Cont.)

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MCL SCAT TRANS	AERCSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION	NITRIC ACIC TRANS
900	11.1111	.5943	.9646	1.0000	1.0000	1.0000	.9106	1.0000	.6774	.2614	1.0128	1.0000
905	11.0497	.5980	.9612	.9981	1.0000	1.0000	.9124	1.0000	.6833	.254[illegible]	3.0228	1.0000
910	10.9890	.6025	.9600	.9969	1.0000	1.0000	.9140	1.0000	.6888	.2467	5.0105	1.0000
915	10.9290	.6050	.9594	.9948	1.0000	1.0000	.9156	1.0000	.6923	.2399	6.9656	1.0000
920	10.8696	.6030	.9617	.9923	1.0000	1.0000	.9172	1.0000	.6958	.2330	8.9406	1.0000
925	10.8108	.6210	.9775	.9874	1.0000	1.0000	.9187	1.0000	.6993	.2263	10.8445	1.0000
930	10.7527	.6224	.9798	.9823	1.0000	1.0000	.9201	1.0000	.7028	.2195	12.7288	1.0000
935	10.6952	.6236	.9811	.9768	1.0000	1.0000	.9215	1.0000	.7063	.2127	14.6105	1.0000
940	10.6383	.6231	.9783	.9726	1.0000	1.0000	.9228	1.0000	.7097	.2060	16.4952	1.0000
945	10.5820	.6193	.9710	.9693	.9999	1.0000	.9241	1.0000	.7121	.1999	18.3990	1.0000
950	10.5263	.6126	.9657	.9670	.9993	1.0000	.9254	1.0000	.7094	.1976	20.3359	1.0000
955	10.4712	.6084	.9612	.9682	.9985	1.0000	.9266	1.0000	.7068	.1954	22.2939	1.0000
960	10.4167	.6043	.9594	.9676	.9975	1.0000	.9277	1.0000	.7041	.1931	24.2696	1.0000
965	10.3627	.6016	.9567	.9670	.9958	1.0000	.9288	1.0000	.7016	.1909	26.2620	1.0000
970	10.3093	.5952	.9581	.9625	.9931	1.0000	.9299	1.0000	.6990	.1886	28.2859	1.0000
975	10.2564	.5930	.9600	.9625	.9899	1.0000	.9309	1.0000	.6965	.1864	30.3207	1.0000
980	10.2041	.5938	.9663	.9682	.9814	1.0000	.9319	1.0000	.6940	.1842	32.3517	1.0000
985	10.1523	.5966	.9735	.9772	.9719	1.0000	.9328	1.0000	.6916	.1820	34.3689	1.0000
990	10.1010	.5918	.9794	.9862	.9523	1.0000	.9337	1.0000	.6892	.1799	36.4097	1.0000
995	10.0503	.5797	.9702	.9943	.9364	1.0000	.9346	1.0000	.6868	.1777	38.5110	1.0000
1000	10.0000	.5582	.9600	.9971	.9107	1.0000	.9355	1.0000	.6845	.1756	40.7195	1.0000
1005	9.9502	.5379	.9548	.9986	.8867	1.0000	.9363	1.0000	.6796	.1755	43.0305	1.0000
1010	9.9010	.5163	.9472	.9982	.8644	1.0000	.9370	1.0000	.6749	.1754	45.4466	1.0000
1015	9.8522	.4941	.9374	.9964	.8418	1.0000	.9378	1.0000	.6702	.1753	47.9766	1.0000
1020	9.8039	.4837	.9448	.9939	.8246	1.0000	.9385	1.0000	.6656	.1753	50.5577	1.0000
1025	9.7561	.4747	.9433	.9890	.8196	1.0000	.9392	1.0000	.6610	.1752	53.1843	1.0000
1030	9.7087	.4675	.9456	.9845	.8137	1.0000	.9399	1.0000	.6566	.1751	55.8470	1.0000
1035	9.6618	.4362	.9522	.9772	.7643	1.0000	.9405	1.0000	.6522	.1750	58.6658	1.0000
1040	9.6154	.4435	.9555	.9714	.7836	1.0000	.9412	1.0000	.6479	.1749	61.4435	1.0000
1045	9.5694	.4837	.9568	.9625	.8665	1.0000	.9418	1.0000	.6436	.1749	64.0302	1.0000
1050	9.5238	.4382	.9522	.9596	.7959	1.0000	.9423	1.0000	.6394	.1748	66.6393	1.0000
1055	9.4787	.4221	.9430	.9563	.7773	1.0000	.9429	1.0000	.6353	.1747	69.7288	1.0000
1060	9.4340	.4298	.9383	.9557	.8049	1.0000	.9434	1.0000	.6313	.1746	72.5796	1.0000
1065	9.3897	.4450	.9336	.9537	.8441	1.0000	.9439	1.0000	.6273	.1745	75.3545	1.0000
1070	9.3458	.4750	.9393	.9490	.9052	1.0000	.9444	1.0000	.6234	.1745	77.9796	1.0000
1075	9.3023	.5126	.9409	.9482	.9814	1.0000	.9449	1.0000	.6195	.1744	80.4168	1.0000
1080	9.2593	.5225	.9516	.9530	.9899	1.0000	.9453	1.0000	.6157	.1743	82.8041	1.0000
1085	9.2166	.5269	.9516	.9659	.9906	1.0000	.9458	1.0000	.6120	.1742	85.1693	1.0000
1090	9.1743	.5255	.9448	.9753	.9910	1.0000	.9462	1.0000	.6082	.1739	87.5419	1.0000
1095	9.1324	.5229	.9346	.9869	.9910	1.0000	.9466	1.0000	.6043	.1733	89.9277	1.0000
1100	9.0909	.5151	.9192	.9941	.9912	1.0000	.9470	1.0000	.6005	.1728	92.3523	1.0000
1105	9.0498	.5065	.9056	.9983	.9910	1.0000	.9474	1.0000	.5968	.1723	94.8196	1.0000
1110	9.0090	.5019	.9022	.9991	.9906	1.0000	.9477	1.0000	.5931	.1718	97.3101	1.0000
1115	8.9686	.5031	.9101	.9996	.9902	1.0000	.9481	1.0000	.5892	.1715	99.7944	1.0000
1120	8.9286	.5045	.9192	.9990	.9899	1.0000	.9484	1.0000	.5852	.1714	102.2719	1.0000
1125	8.8889	.5057	.9290	.9976	.9896	1.0000	.9487	1.0000	.5813	.1712	104.7432	1.0000
1130	8.8496	.5060	.9374	.9952	.9899	1.0000	.9490	1.0000	.5774	.1711	107.2130	1.0000
1135	8.8106	.4959	.9273	.9911	.9910	1.0000	.9493	1.0000	.5736	.1709	109.7335	1.0000
1140	8.7719	.4970	.9220	.9833	.9928	1.0000	.9496	1.0000	.5698	.1707	112.2983	1.0000
1145	8.7336	.4789	.9181	.9753	.9945	1.0000	.9499	1.0000	.5661	.1706	113.6012	1.0000

INTEGRATED ABSORPTION FROM 900 TO 1145 CM-1 = 113.60AVERAGE TRANSMITTANCE = .5363

10. EXAMPLES OF TRANSMITTANCE AND RADIANCE SPECTRA

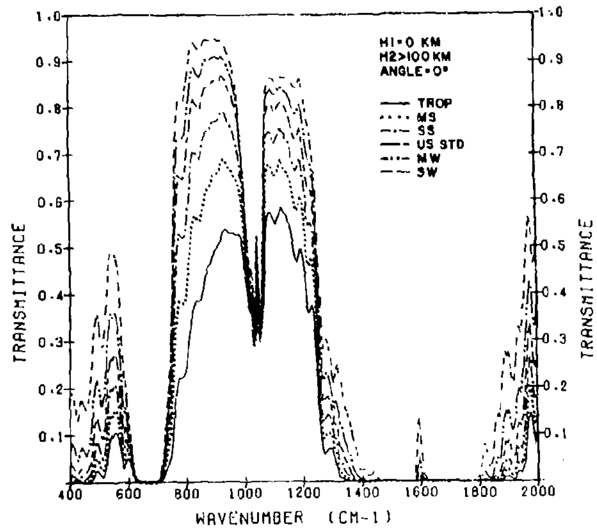
Some examples of transmittance and radiance spectra obtained from LOWTRAN 5 are presented in Figures 28 through 41. Figures 28 to 30 show the variations in transmittance and radiance with the six model atmospheres for three atmospheric paths. The rural aerosol model, with a 23-km VIS, was used for the boundary layer, and the default aerosol models for the rest of the atmosphere. The spectral regions shown are between 400 and 2000 cm^{-1} and between 2000 and 3600 cm^{-1}.

Figures 31 to 38 show the variation in transmittance and radiance with atmospheric slant path for the U.S. Standard model atmosphere and the rural, 23-km VIS, aerosol model for the spectral region between 400 and 4000 cm^{-1}. These figures show the range of observer altitudes, zenith angles, and atmospheric slant paths to which the code can be applied to model transmittance and radiance for specific atmospheric problems.

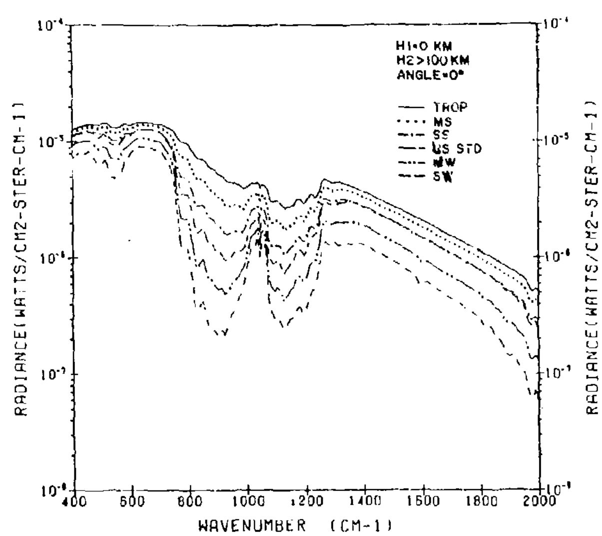
Figure 39 shows the transmittance from ground to space from 0.25 to 4 μm. This calculation used the U.S. Standard model atmosphere and the rural aerosol model with a 23-km VIS.

Figure 40 shows the variation in transmittance in the spectral region between 400 and 4000 cm^{-1} for the rural, maritime, urban, and tropospheric aerosol models. The calculation is for a 10-km horizontal sea-level path using the U.S Standard model atmosphere and a 23-km VIS.

Figure 41 shows the transmittance of the two fog models in LOWTRAN for a 0.2-km horizontal sea-level path and a 1-km VIS in the spectral regions from 400 to 4000 cm^{-1}.

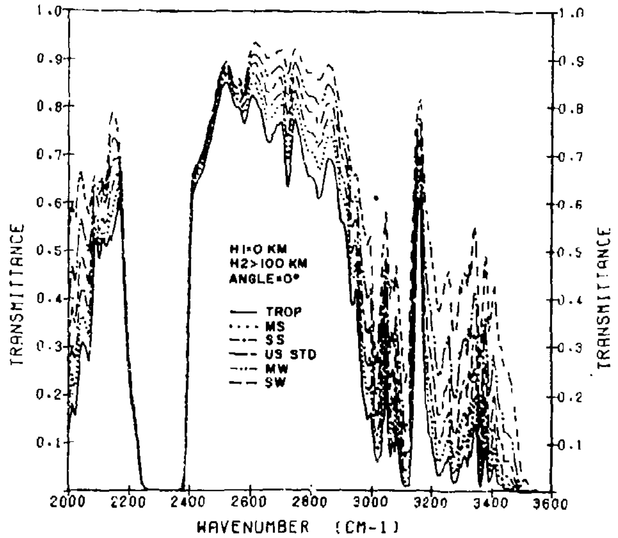


a. transmittance, from 400 to 2000 cm^{-1}

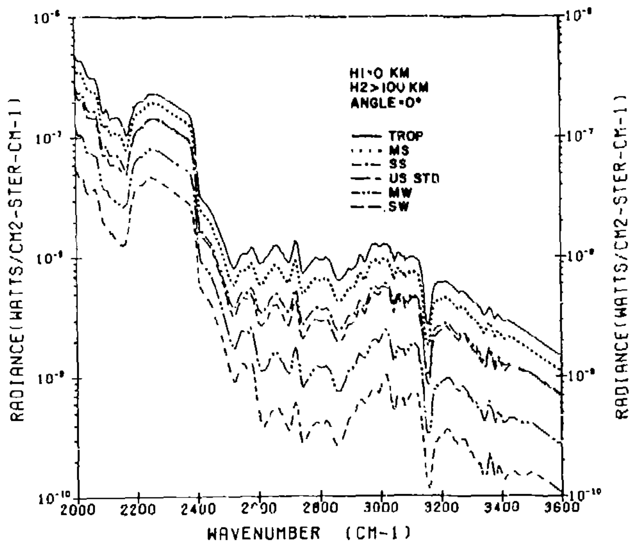


b. radiance, from 400 to 2000 cm^{-1}

Figure 28. Transmittance and Radiance Spectra for a Vertical Path Looking to Space From the Ground (H1 = 0, H2 ≥ 100 km, ANGLE = 0°), with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres

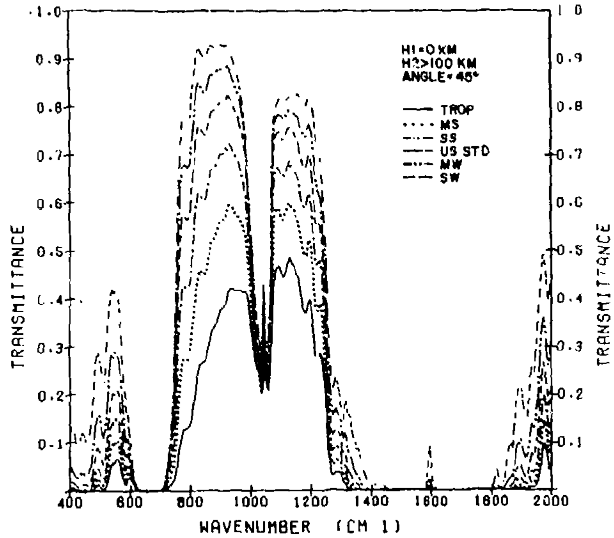


c. transmittance, from 2000 to 3600 cm^{-1}

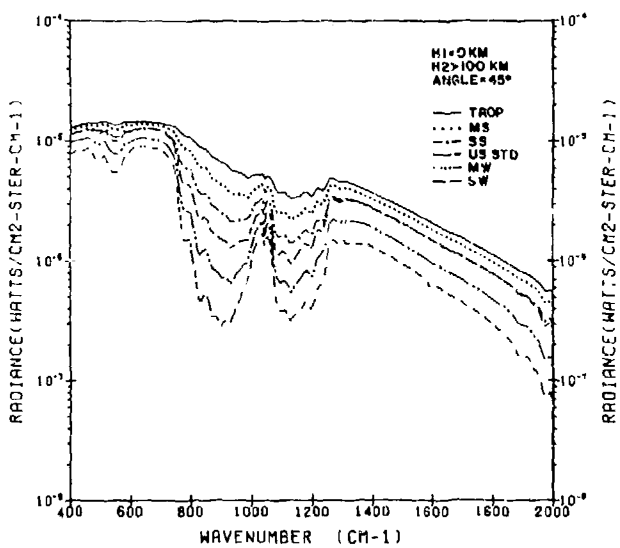


d. radiance, from 2000 to 3600 cm^{-1}

Figure 28. Transmittance and Radiance Spectra for a Vertical Path Looking to Space From the Ground (H1 = 0, H2 ≥ 100 km, ANGLE = 0°), with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres (Cont.)

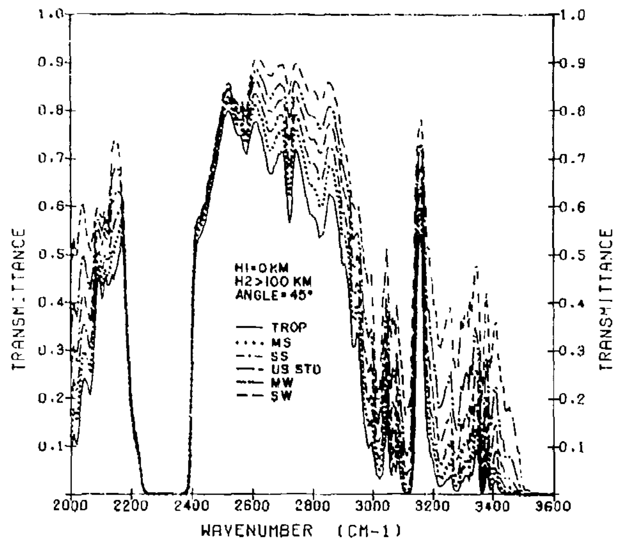


a. transmittance, from 400 to 2000 cm^{-1}

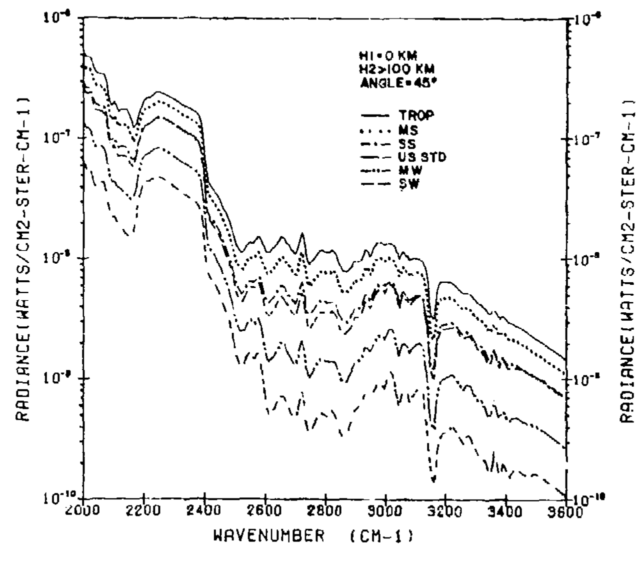


b. radiance, from 400 to 2000 cm^{-1}

Figure 29. Transmittance and Radiance Spectra for a Slant Path at 45° Looking to Space From the Ground (H1 = 0, H2 ≥ 100 km, ANGLE = 45°) with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres

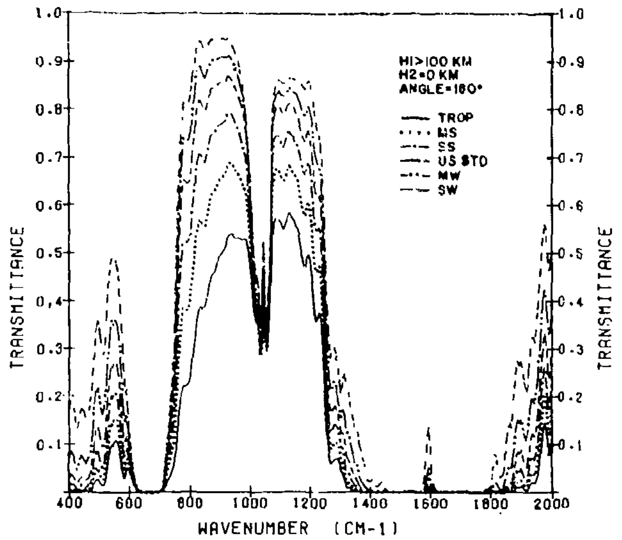


c. transmittance, from 2000 to 3600 cm^{-1}

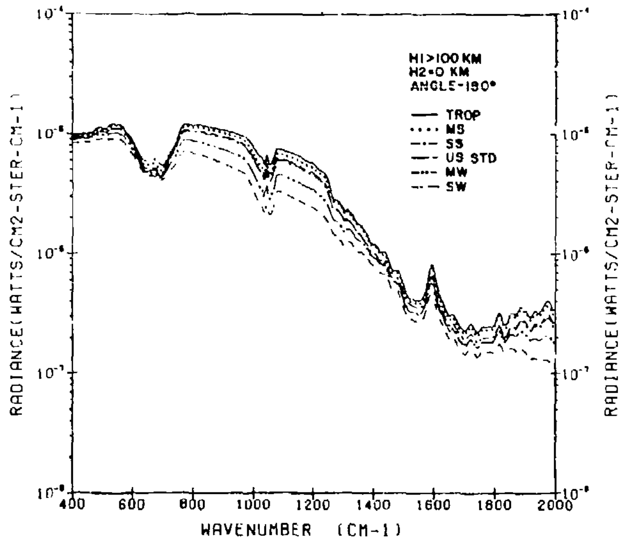


d. radiance, from 2000 to 3600 cm^{-1}

Figure 29. Transmittance and Radiance Spectra for a Slant Path at 45° Looking to Space From the Ground (H1 = 0, H2 ≥ 100 km, ANGLE = 45°) with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres (Cont.)

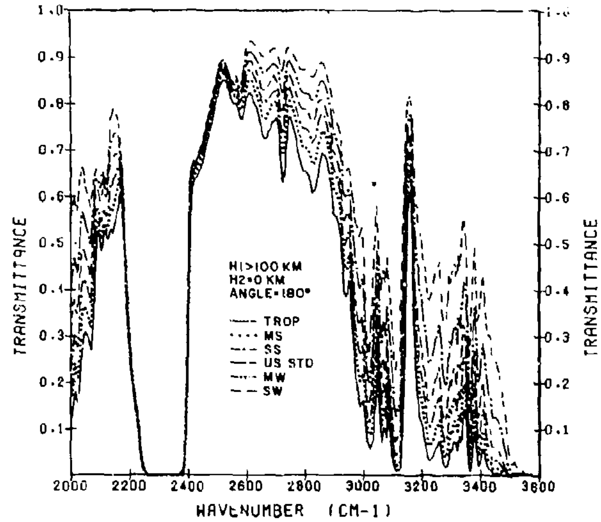


a. transmittance from 400 to 2000 cm^{-1}

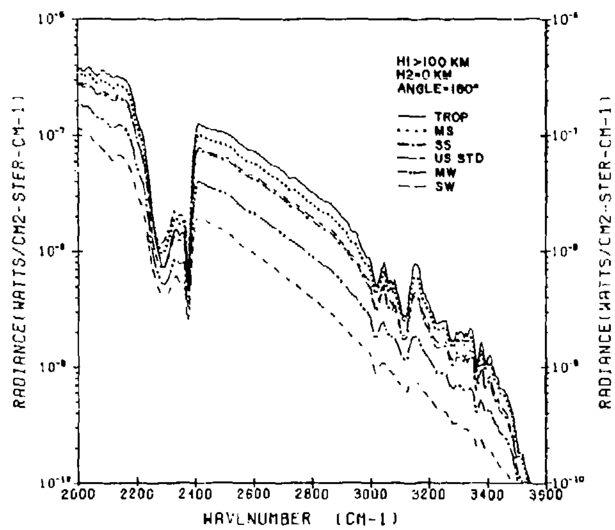


b. radiance from 400 to 2000 cm^{-1}

Figure 30. Transmittance and Radiance Spectra for a Vertical Path Looking at the Ground From Space ($H1 \geq 100$ km, H2 = 0, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and for the Six Model Atmospheres

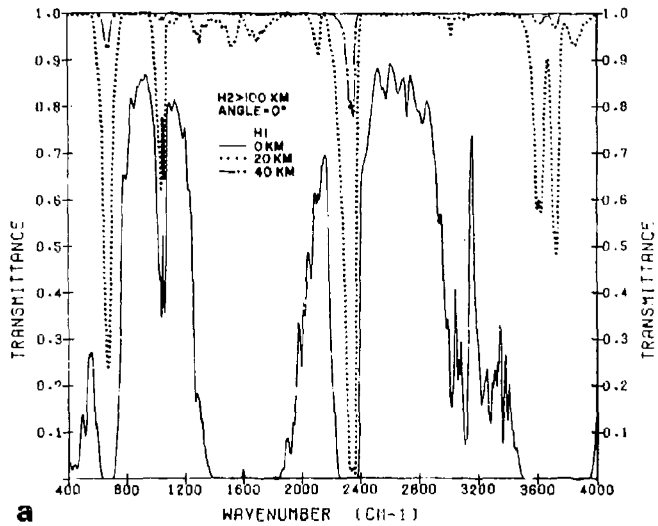


c. transmittance from 2000 to 3600 cm^{-1}

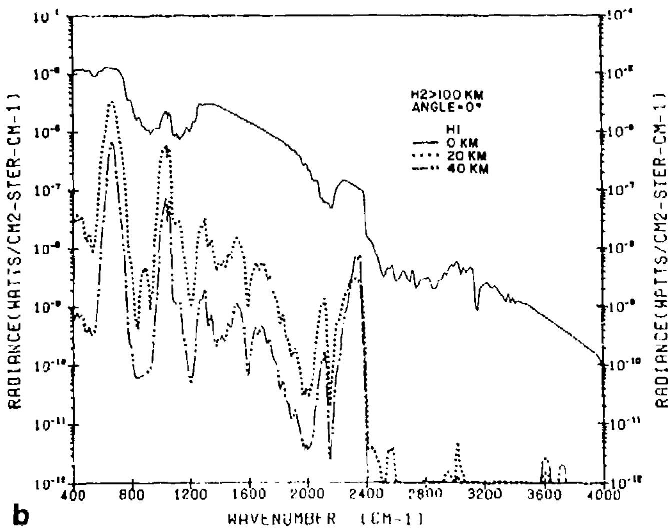


d. radiance from 2000 to 3600 cm^{-1}

Figure 30. Transmittance and Radiance Spectra for a Vertical Path Looking at the Ground From Space (H1 ≥ 100 km, H2 = 0, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and for the Six Model Atmospheres (Cont.)



a



b

Figure 31. Transmittance and Radiance Spectra for a Vertical Path Looking to Space From H1 (H1 = 0, 20 km, 40 km, H2 ≥ 100 km, ANGLE = 0°) the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6), From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

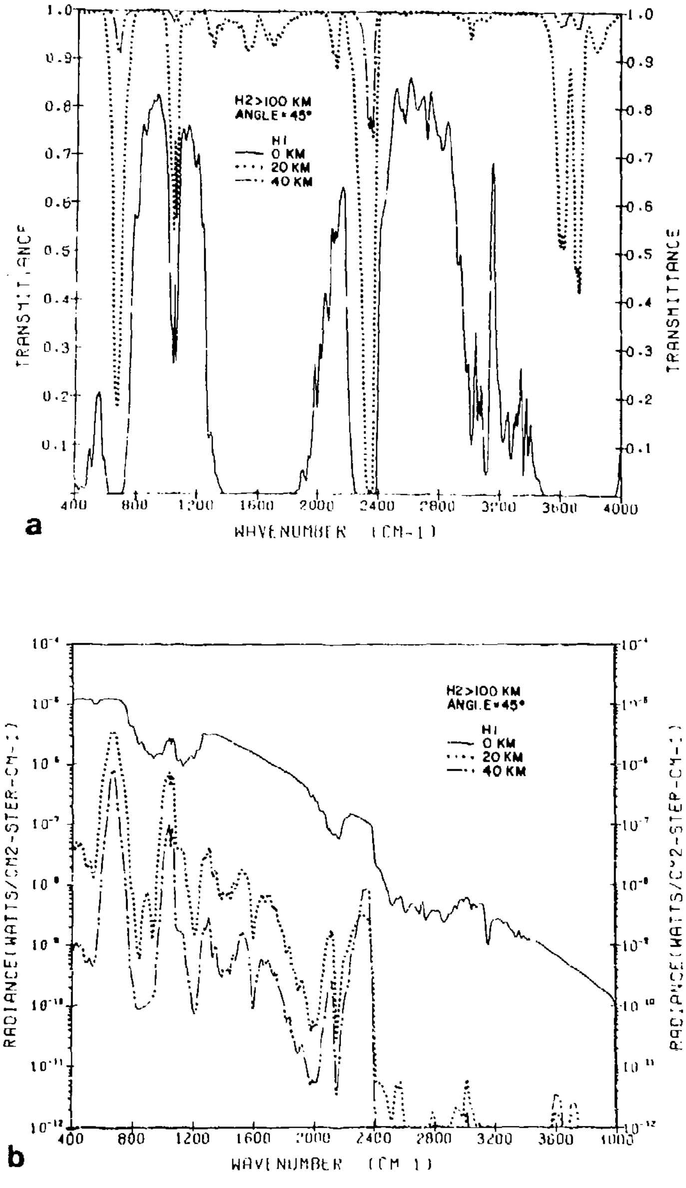


Figure 32. Transmittance and Radiance Spectra for a Slant Path at 45° Looking to Space From H1 (H1 = 0, 20 km, 40 km, ANGLE = 45°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

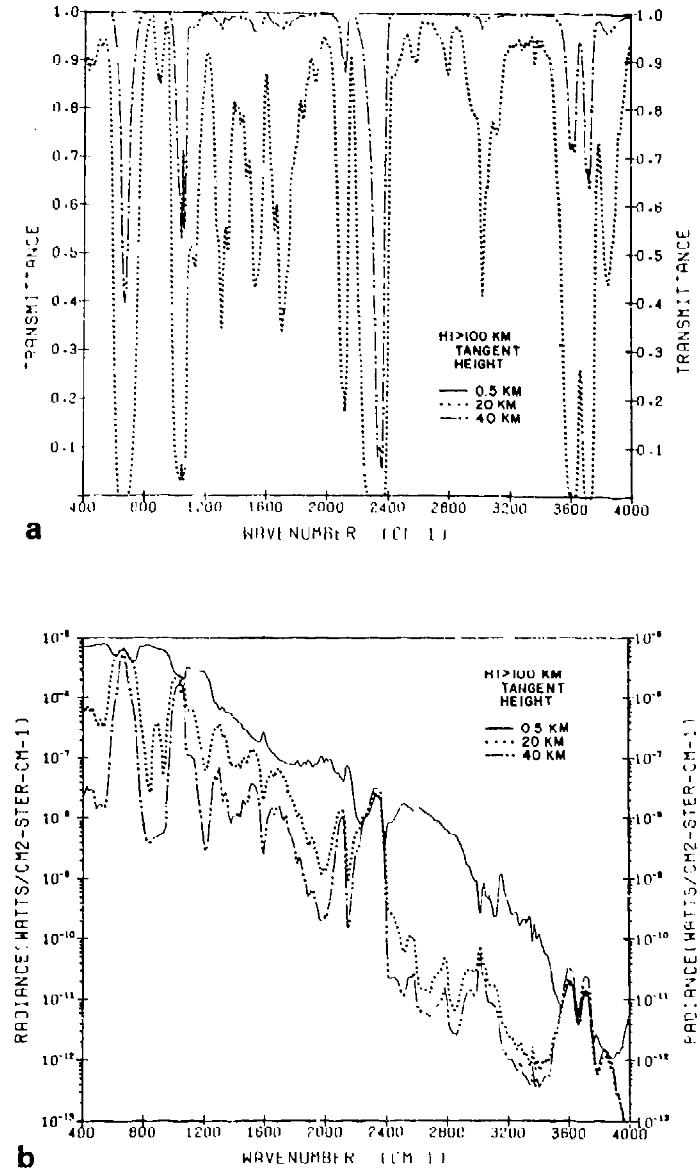
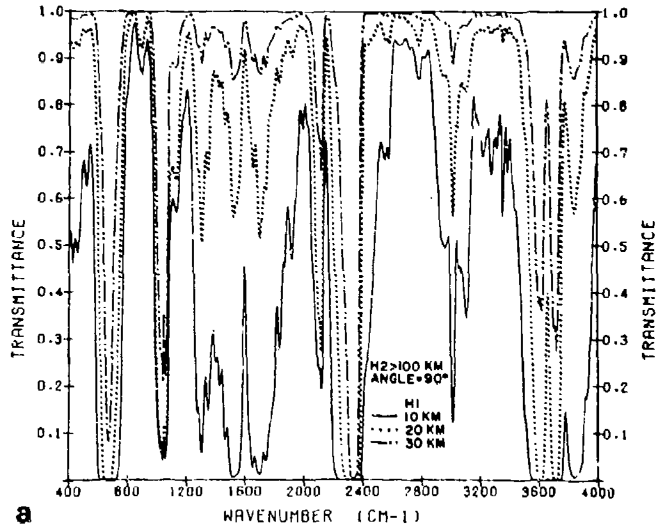
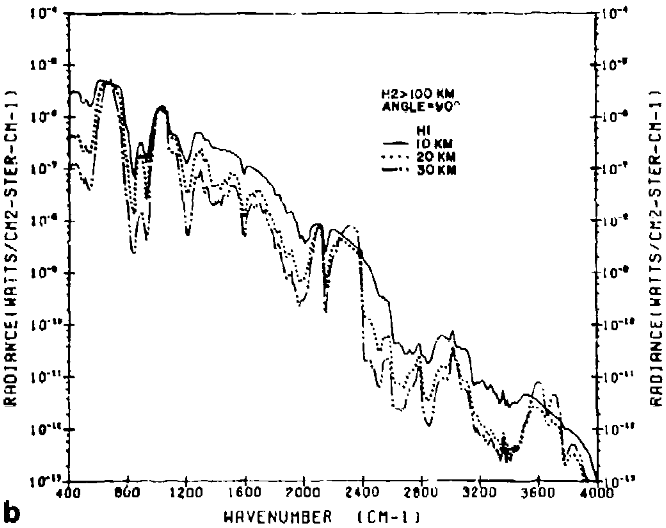


Figure 33. Transmittance and Radiance Spectra for a Slant Path Looking From Space to Space Through a Tangent Height of HMIN (ITYPE = 3, H1 ≥ 100 km, HMIN = 0.5 km, 20 km, 40 km) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere, From 400 to 4000 cm^{-1}:
a. transmittance (for HMIN = 0.5 km, the transmittance is ~ zero between 400 and 4000 cm^{-1}),
b. radiance

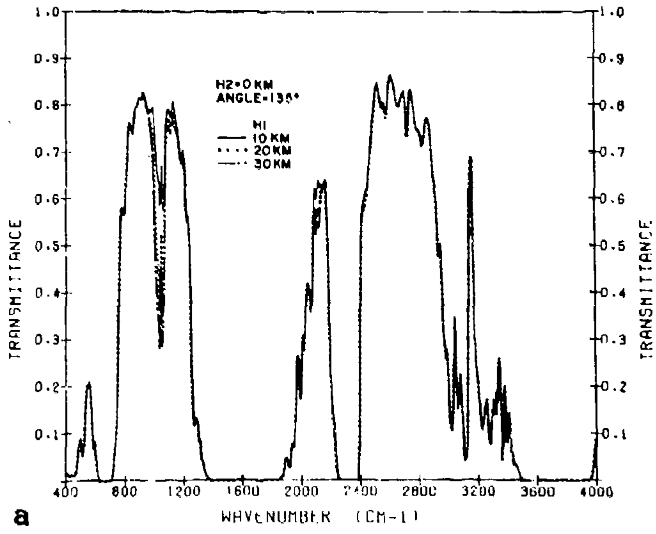


a

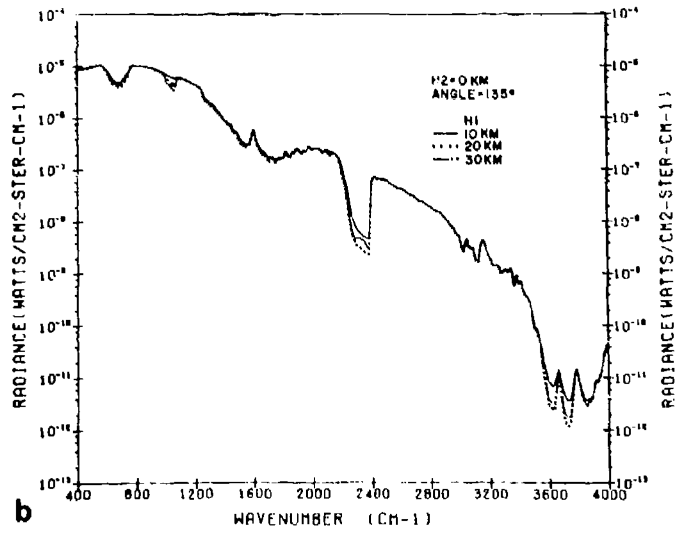


b

Figure 34. Transmittance and Radiance Spectra for a Slant Path Looking to Space From a Tangent Height of H1 (ITYPE = 3, H1 = 10, 20, 30 km, ANGLE = 90°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6); From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

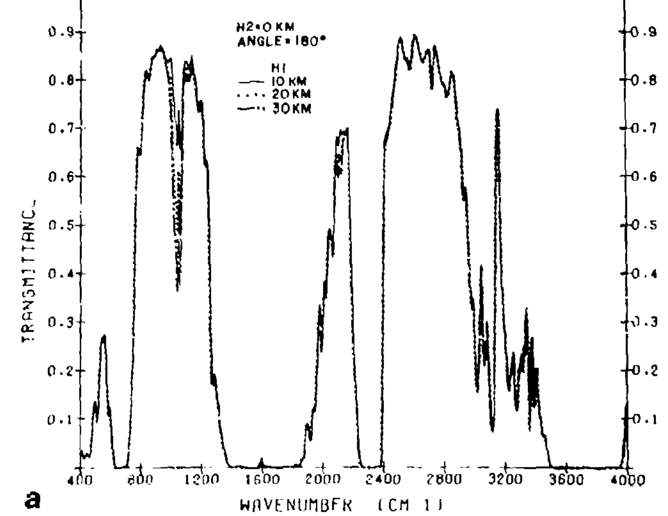


a

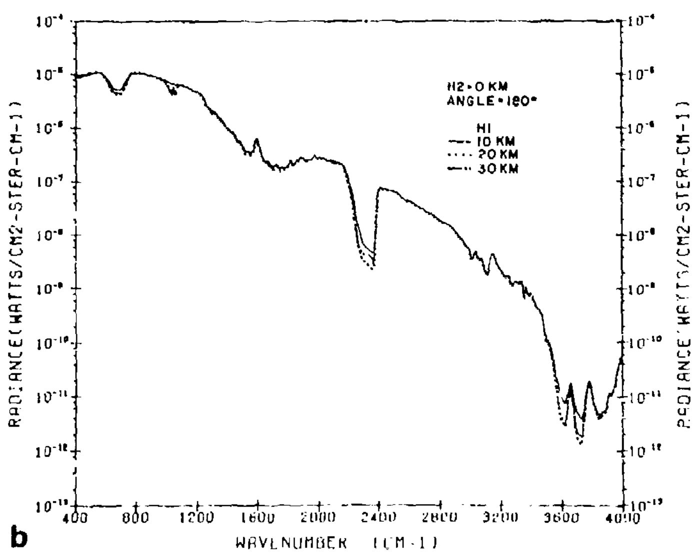


b

Figure 35. Transmittance and Radiance Spectra for a Slant Path Looking to the Ground From H1 (H1 = 10, 20, 30 km, H2 = 0 km, ANGLE = 135°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6), From 400 to 4000 cm^{-1}: a. transmittance, b. radiance



a



b

Figure 36. Transmittance and Radiance Spectra for a Vertical Path Looking at the Ground From H1 (H1 = 10, 20, 30 km, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

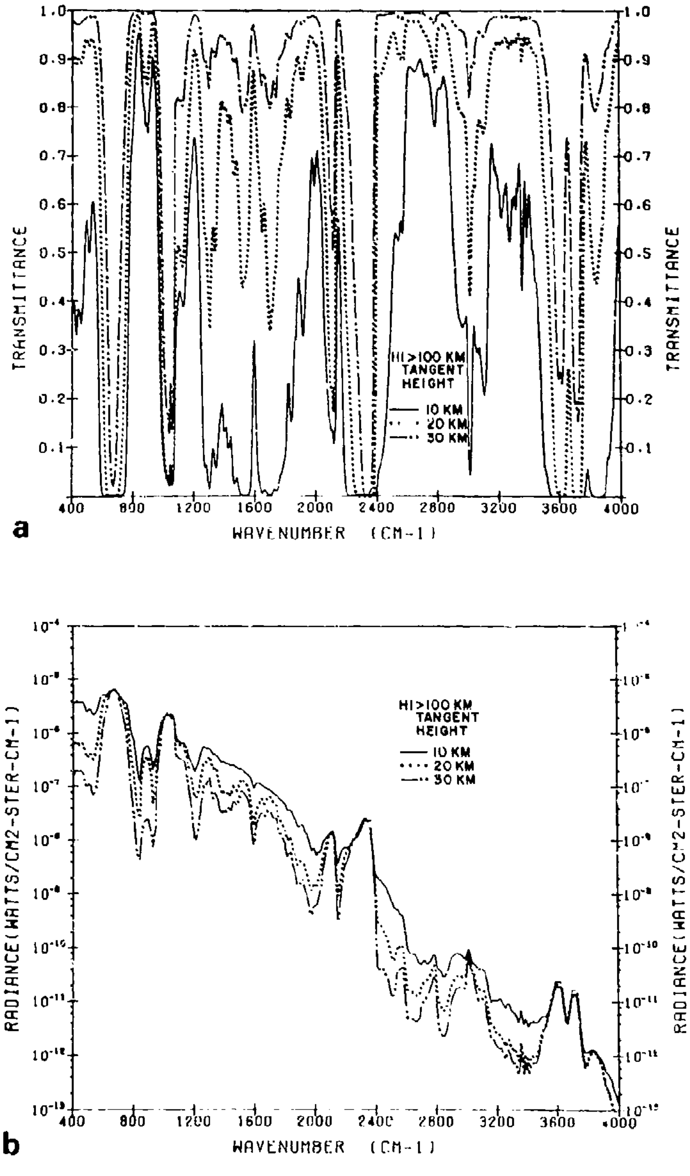


Figure 37. Transmittance and Radiance Spectra for a Slant Path From Space to Space Through a Tangent Height HMIN (ITYPE = 3, H1 ≥ 100 km, HMIN = 10, 20, 30 km) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

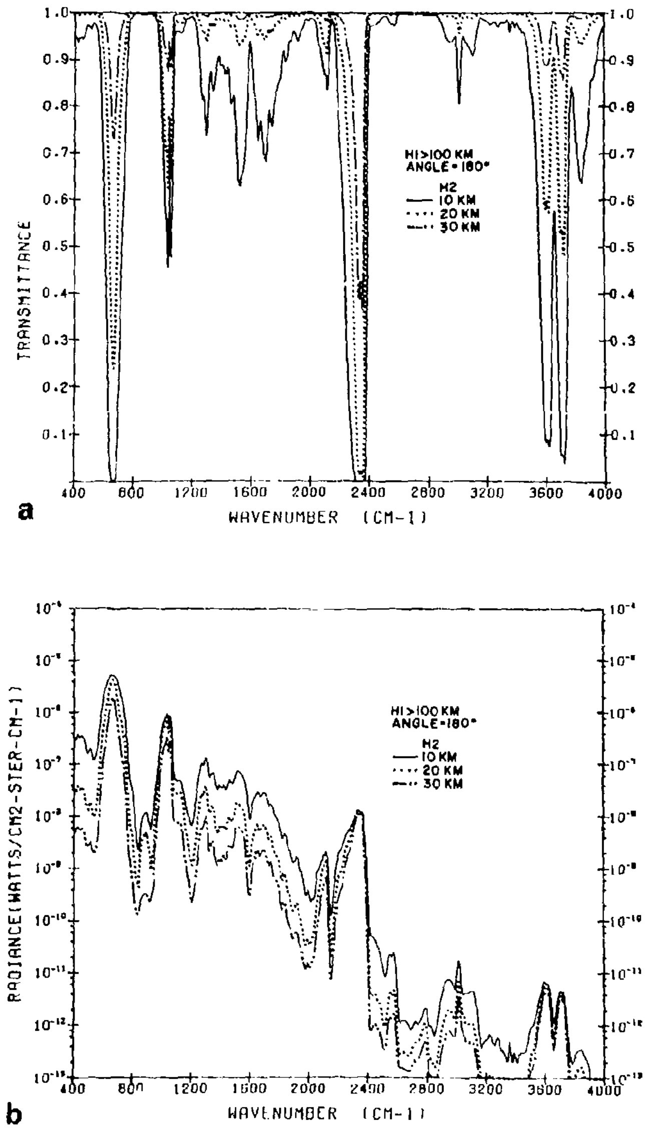


Figure 38. Transmittance and Radiance Spectra for a Vertical Path Looking From Space to H2 (H1 > 100 km, H2 = 10, 20, 30 km, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance (atmospheric radiance only, assuming no boundaries)

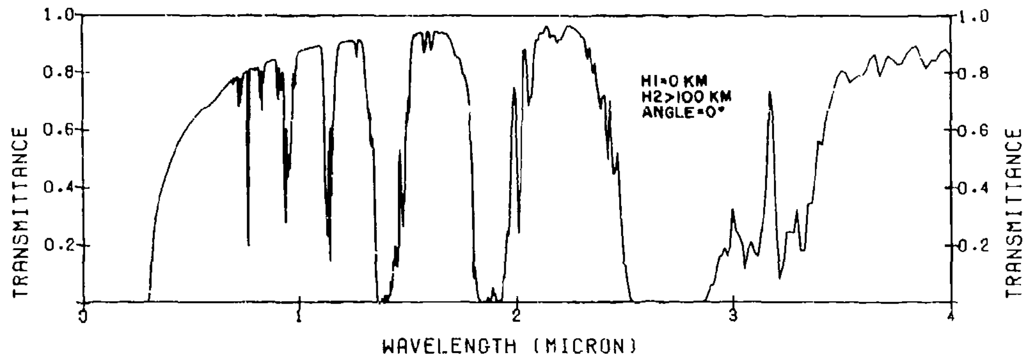


Figure 39. Transmittance Spectra for a Vertical Path From Ground to Space From 0.25 to 4 μ, Using the Rural Aerosol Model, 23-km VIS and the U.S. Standard Model Atmosphere

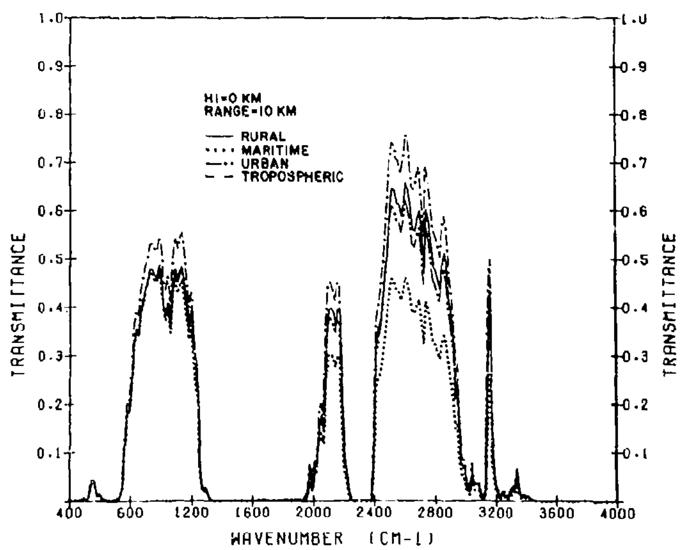


Figure 40. Transmittance Spectra for a 10-km Horizontal Path at Sea Level for the Rural, Maritime, Urban, and Tropospheric Aerosol Models Using the U.S. Standard Model Atmosphere and a VIS of 23 km

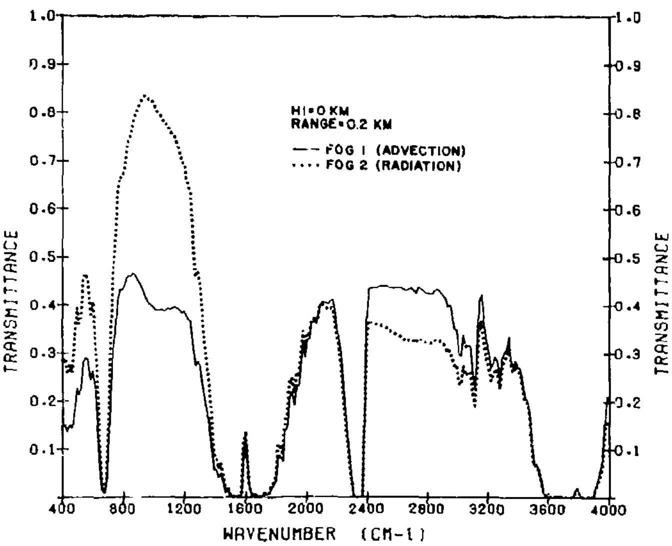


Figure 41. Transmittance Spectra for the Advection Fog (Fog 1) and the Radiation Fog (Fog 2) Models, for a 0.2-km Horizontal Path at Sea Level, With the U.S. Standard Model Atmosphere and a 1-km VIS, From 400 to 4000 cm^{-1}

11. AEROSOL MODEL COMPARISON WITH MEASUREMENTS

Between January and September 1970, EMI Ltd. made a series of measurements of infrared transmittance at various wavelengths over the sea.[80, 81] Under the conditions of the setup, the experiment was largely a measurement of aerosol extinction and it provides a data set against which the LOWTRAN maritime aerosol model can be tested. This section will review these measurements briefly and compare them with LOWTRAN calculations.

11.1 Measurements

The EMI measurements were made over a 20-km path across Mounts Bay at the southwestern tip of England. Most of the path was several kilometers offshore. The source for the transmittance measurements was a 3800-K carbon arc blackbody while the receiver was a Golay cell mounted at the focus of a 76-cm diameter

80. Arnold, D.H., Lake, D.B., and Sanders, R. (1970) Comparative Measurements of Infrared Transmission Over a Long Overseas Path, EMI Report DMP 3736.

81. Arnold, D.H. and Sanders, R. (1971) Comparative Measurements of Infrared Transmission Over A Long Overseas Path, EMI Report DMP 3858.

mirror. Various filters could be placed in front of the detector. In this report, data will be presented on three filters: their filter response functions are shown in Figure 42.

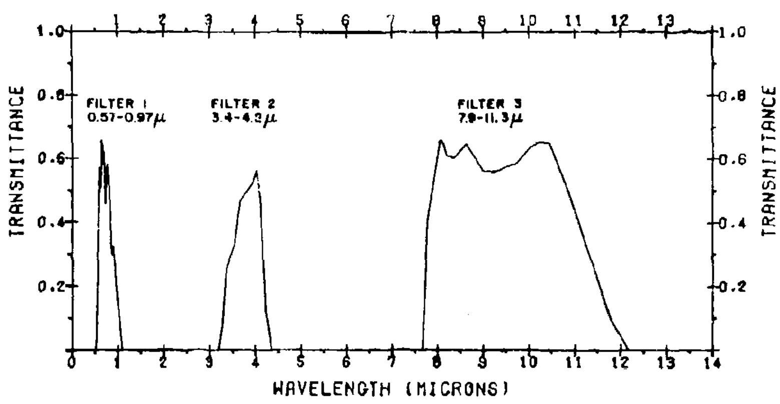


Figure 42. System Response Functions for Three of the Filters From the EMI Measurements: 1. 0.57 to 0.97 μ; 2. 3.5 to 4.2 μ; 3. 7.9 to 11.3 μ

In addition to the transmittance, other physical parameters were measured at one end of the path, including: air temperature, relative humidity (from a wet and dry bulb thermometer), wind speed (estimated according to the Beaufort scale), wind direction, and visibility (estimated by an observer viewing six landmarks around Mounts Bay). A block of data consisted of the measurement of these physical parameters plus the detector response for each of the filters consecutively.

11.2 Calibration

The measurements were calibrated by selecting one particular data block with the highest (relative) measured transmittance for the 7.9- to 11.3-μ filter: for this case the absolute transmittance was calculated using the data from Altshuler.[82] Comparing the absolute calculated value of the transmittance with the relative measured value allowed the baseline for this filter to be set. The system response for the other filters relative to the 7.9- to 11.3-μ filter was also measured over a short path with negligible attenuation. From the absolute transmittance for the 7.9- to 11.3-μ filter and the relative responses of the other filters, the baselines for the other filters could be set.

82. Altshuler, T.L. (1961) Infrared Transmission and Background Radiation by Clear Atmospheres, GE Report 61SD 199, AD401923.

The data are actually presented as "effective atmospheric extinction coefficients" σ which are related to the filter-averaged transmittance $\overline{T}$ by

$$\sigma = -(\ln \overline{T})/L \tag{32}$$

where L is the path length; in this case 20 km. (Note that σ is merely the log of the transmittance and is not comparable to a band model extinction coefficient. Since the transmittances span four orders of magnitude, it is necessary to present the data on a log scale.) As will be seen later, the quality of the calibration appears to be good.

11.3 LOWTRAN Calculations

To compare with the measured transmittances, the equivalent filter-weighted transmittance for each data block was calculated using LOWTRAN 5. The required inputs to LOWTRAN were given by the path length (20.0 km) the pressure (assumed to be 1013.25 mb), and the measured temperature and relative humidity. The inputs relating to the aerosol extinction are the aerosol model and the meteorological range. For most calculations the maritime aerosol model was used. However, the observer-estimated value of visual range reported in the data was found to be inaccurate and unrepresentative of the conditions along the path.

To circumvent this problem with the observer estimated visibility, it was decided to use the measured value of the extinction for filter 1 (0.57-0.97 μ) to derive a value for the meteorological range. The meteorological range, VIS, is defined as the path length over which the transmittance at 0.55 μ is 0.02. From this definition and from Beer's law

$$\mathrm{VIS} = \frac{3.912}{\sigma(0.55)} \tag{33}$$

where σ (0.55) is the total extinction coefficient at 0.55 μ and 3.912 = ln (0.02). (See footnote on page 22, Section 3.2.)

In the spectral region from 0.57 μ to 0.97 μ, the extinction coefficient is dominated by the aerosol extinction coefficient which in LOWTRAN depends only upon the wavelength, VIS, and to a lesser extent, the relative humidity. Neglecting the relative humidity dependence for now, if $\sigma_1{}^*$ is the calculated mean filter-weighted aerosol extinction coefficient for filter 1, then $\sigma_1{}^* = \sigma\,(0.55)\,B$, where B is a constant. One can then write

$$\mathrm{VIS} = \frac{3.912 \times B}{\sigma_1{}^*} \tag{34}$$

Now between 0.57 and 0.97 μ, the aerosol extinction coefficient varies slowly with wavelength, especially for the maritime aerosol model (see Figure 10a). For this reason we can approximate $\sigma_1{}^*$ by the measured effective atmospheric extinction coefficient σ_1 (Eq. (32)) even though the spectral weighting is different for the two quantities. Therefore, to the degree of approximation noted above, one can write

$$VIS = 3.912 \times B/\sigma_1$$

In practice, the constant B was determined empirically by assuming an initial value of B and calculating the "effective extinction coefficient" (that is, $-L^{-1} \ln \overline{T}_1$, where $\overline{T}_1$ is mean transmittance for filter 1 calculated by LOWTRAN) for each case in the data set. B was then adjusted until the mean of this value averaged over the sample equalled the mean of the measured values σ_1.

11.4 Results of the Comparison

This section will present the results of the comparison of the measured and calculated extinctions for various subsets of the measured data. In the figures to be presented, the axes will represent the "effective extinction coefficient", that is, $(-\ln \overline{T})/L$, where $\overline{T}$ is the filter-weighted mean transmittance over the path length $L = 20$ km. The solid line in each figure is a 45° line through the origin while the dashed line is a least-squares fit of the calculated extinctions to the measured ones. Note that since both the measured and the calculated extinctions contain errors, simple least-squares theory is not strictly applicable in this case.

Figure 43 shows the calculated vs the measured effective extinction coefficient for the 7.9- to 11.3-μ filter for the 50 cases of highest meteorological range (that is, the lowest extinction in filter 1). The maritime aerosol model was used in the calculations; however, due to the combination of the spectral region and the high visibility, the maximum calculated aerosol extinction in these cases is less than 0.02 km^{-1}. This graph then is primarily a demonstration of molecular extinction.

The regression line gives an indication of the quality of fit. The fact that the y-intercept is nearly zero indicates that the calibration of the measurements is good while the slope of the line of 1.09 indicates that the average fit is within 10 percent. The standard deviation about the regression line is 0.016 km^{-1}; the random uncertainty between the measured and the calculated extinctions can be taken as plus or minus two standard deviations or ±0.032 km^{-1}. The mean transmittance for this set of points is about 0.09. For the level of transmittance, the uncertainty in the "effective extinction coefficient" of ±0.032 km^{-1} translates to an uncertainty in the transmittance of about ±0.06.

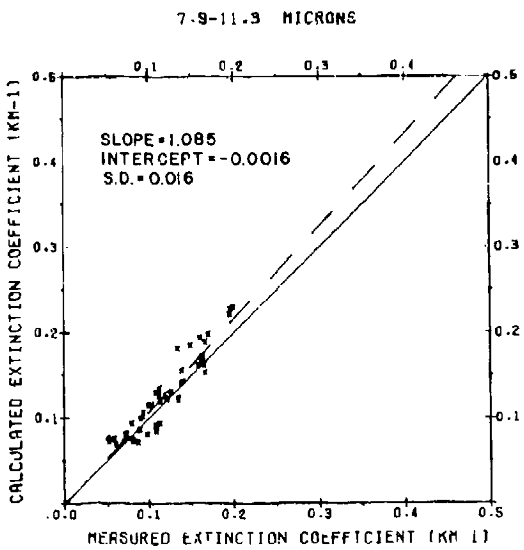
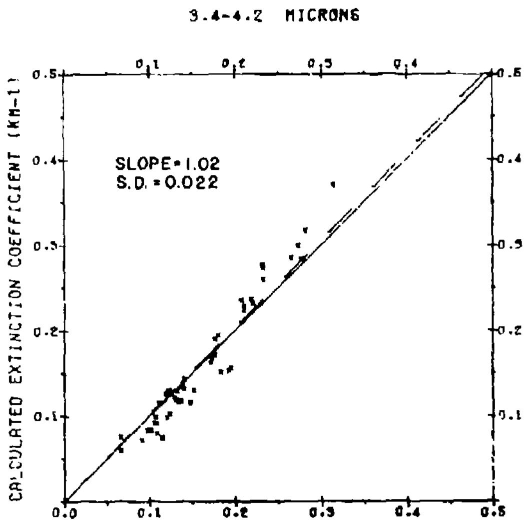


Figure 43. Comparison of the Calculated vs the Measured "Effective Extinction Coefficients" for the 7.9- to 11.3-μ Filter for the 50 Cases of Highest VIS, Using the Maritime Aerosol Model. The dashed line is a simple least-squares fit of the calculated to the measured data: the slope, the intercept and the standard deviation about the regression line are given

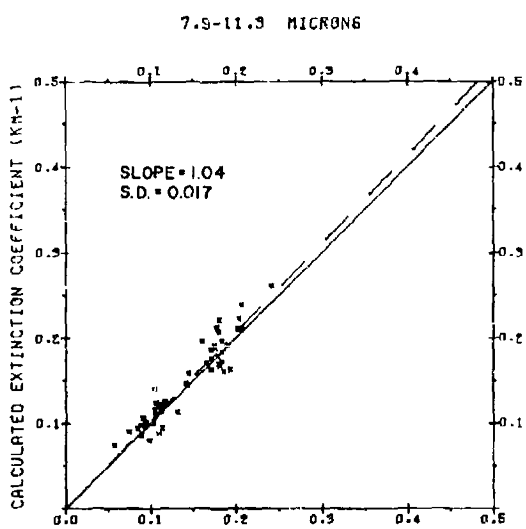
Since the calibration error appears to be negligible, all further regression lines will be constrained to pass through the origin.

The maritime aerosol model is designed to be representative of moderate wind speed conditions over the open ocean. To test the validity of this model, those cases for which the wind was off the ocean and between 6 and 17 m/sec (Beaufort scale 4 to 7) were selected. The results for this subset of the data for the 3.4 to 4.2 μ and for the 7.9- to 11.3-μ filters are shown in Figures 44a and b. In both cases, slope of the regression line is not significantly different from 1, indicating a good average fit between the calculated and the measured extinctions. Also, the standard deviations about the regression lines are not significantly greater than that in Figure 43, indicating the same level of random error.

To demonstrate the results when an inappropriate aerosol model is used, the subset of the cases for which the wind was offshore was chosen and the LOWTRAN transmittances were calculated, again using the maritime aerosol model. The results for the 3.4- to 4.2-μ and the 7.9- to 11.3-μ filters are shown in Figures 45a and b. In Figure 45a the calculated extinctions in the 4-μ region are clearly

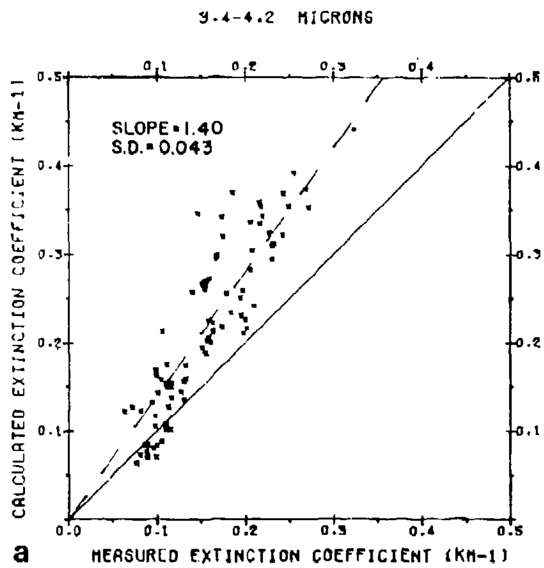


a



b

Figure 44. Calculated vs the Measured "Effective Extinction Coefficients" for the Cases of Onshore Winds of Moderate Intensity, Using the Maritime Aerosol Model: a. 3.4 to 4.2 μ, b. 7.9 to 11.3 μ. The dashed line is a simple least-squares fit through the origin of the calculated to the measured data



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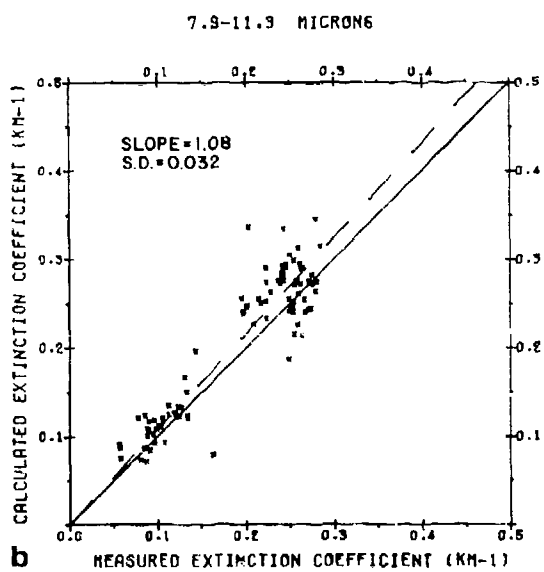

b

Figure 45. Calculated vs Measured "Effective Extinction Coefficients" for the Cases of Offshore Winds, Using the Maritime Aerosol Model: a. 3.4 to 4.2 μ, b. 7.9 to 11.3 μ

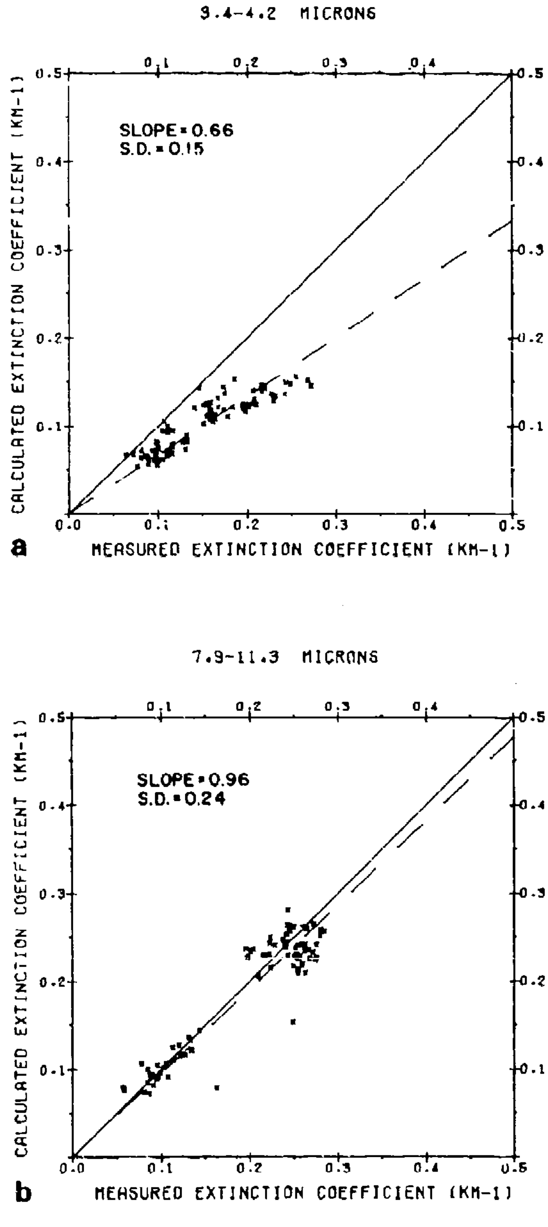

Figure 46. Calculated vs Measured "Effective Extinction Co. fficients" for the Cases of Offshore Winds, Using the Rural Aerosol Model: a. 3.4 to 4.2 μ, b. 7.9 to 11.3 μ

too large, by almost a factor of 2 for the high extinction cases. For the 10-μ filter shown in Figure 45b, the slope of the regression line is only slightly greater than that in Figure 44b, where the proper aerosol model is used, and is the same as in Figure 43, where aerosol extinction is relatively unimportant. The scatter of points in both Figures 45a and b is double that in Figures 44a and b respectively.

Since the maritime aerosol model is inappropriate for these cases for which the wind blows off the land (at least for the shorter wavelengths), these cases were rerun using the rural aerosol model (and adjusting B in Eq. (34) so that LOWTRAN returns the same calculated extinction for filter 1 as was measured). These results are shown in Figures 46a and b. In Figure 46a, the calculated extinction in the 4-μ region are now too low, again by a factor of almost 2 in the high extinction cases. In Figure 46b, the slope of the regression line has been reduced to slightly less than 1.0, but it is still not significantly different from 1.0. The scatter of these points using the rural model is less than those using the maritime model in about the same proportions as the reduction of the slopes of the regression lines.

The conclusions that can be drawn from these data are as follows: in the 4-μ region, the maritime aerosol model provides a reasonably accurate description of open ocean, moderate wind-speed conditions. For air masses originating over land, the maritime model gives far too much extinction. The rural model is not appropriate for the offshore wind cases either, probably because as the wind blows over the short stretch of water it generates sea spray and picks up some marine-type aerosols. For the cases of offshore winds the most appropriate model is some average of the maritime and the rural models.

In the 10-μ region, aerosol extinction is less important than in the 4-μ region, so that the choice of the aerosol model is less critical. Again the maritime model gives an accurate description of an open ocean, moderate wind-speed condition. However, even in situations where an inappropriate aerosol model is used, the results may not be greatly in error.

12. SENSITIVITY TO METEOROLOGICAL INPUT PARAMETERS

In this section, an example of variations in transmittance, calculated from the LOWTRAN model, due to uncertainties in meteorological input parameters is presented. It is given to illustrate one method of determining the sensitivity of the program to meteorological conditions, which could be applied by LOWTRAN users to a specific atmospheric problem. A more definitive study in this area, using a

similar approach for electro-optical systems application, has been carried out by Snyder[83] of the Naval Oceans Systems Center.

In general, the transmittance, $\overline{\tau}_k$, calculated from LOWTRAN for an atmospheric path at a given wavenumber, ν_k, depends on an array of meteorological input parameters, x_i.

$$\overline{\tau}_k = \overline{\tau}(x_1, \ldots, x_i, \ldots, x_N, \nu_k) \tag{35}$$

The N-parameters, x_i, correspond to temperature, pressure, molecular absorber amounts, aerosol type and amounts, meteorological range, path length, etc.

Assuming that the variations in the input parameters, Δx_i, are completely independent, the variation in the total transmittance can be written as

$$\Delta\overline{\tau}_k = \pm \left[\sum_{i=1}^{N} \left(\frac{\partial \overline{\tau}_k}{\partial x_i} \right)^2 (\Delta x_i)^2 \right]^{1/2} \quad . \tag{36}$$

Equation (36) defines the rms variation in total transmittance at the wavenumber, ν_k, for independent variations in the meteorological input parameters. It does not include LOWTRAN model uncertainties such as the band model approximation for molecular absorption or the assumption of homogeneous layering of the atmosphere, with thermal equilibrium in each layer.

Since the transmittance is usually a highly non-linear function of the input parameters, the partial derivatives, $(\partial\overline{\tau}_k/\partial x_i)$, of the transmittance in Eq. (36) must be calculated numerically, starting from a given set of input conditions and a specific atmospheric path. The atmospheric case chosen for this example is a horizontal path of 2 km at sea level, with a meteorological range of 4 km for the rural aerosol model, and the 1962 U.S. Standard atmospheric model. The transmittance for this case from 500 to 3000 cm^{-1} is shown in Figure 47.

The partial derivatives of the transmittance were calculated from this set of starting conditions by successive runs of LOWTRAN in which the various meteorological parameters were varied one at a time between 500 and 3000 cm^{-1}. The partial derivatives of the transmittance were stored in an (NxM) matrix, where N is the number of meteorological parameters varied and M the number of wavenumber points. Figure 48 shows the partial derivative of the transmittance with respect to the water vapor density for this path and Figure 49 the derivative in transmittance with respect to meteorological range.

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83. Snyder, F. P. (1978) The Effects of Meteorological Uncertainties on Electro-Optical Transmittance Calculations, Naval Oceans Systems Center, San Diego, California, NOSC-TN-440.

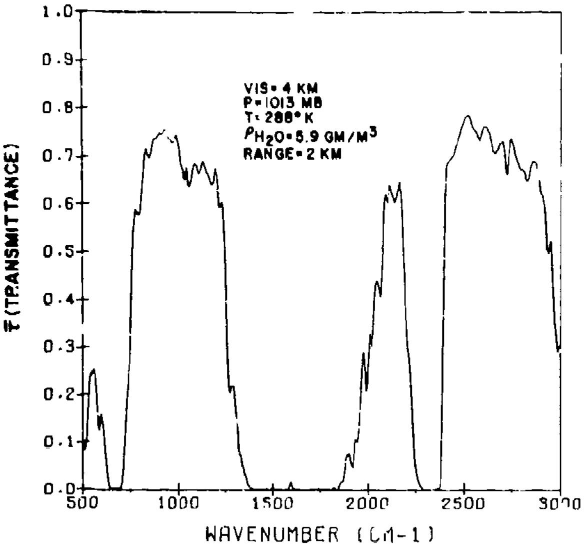

Figure 47. Total Transmittance vs Wavenumber for a 2-km Path at Sea Level With the U.S. Standard Atmosphere Model and a VIS of 4 km for the Rural Aerosol Model

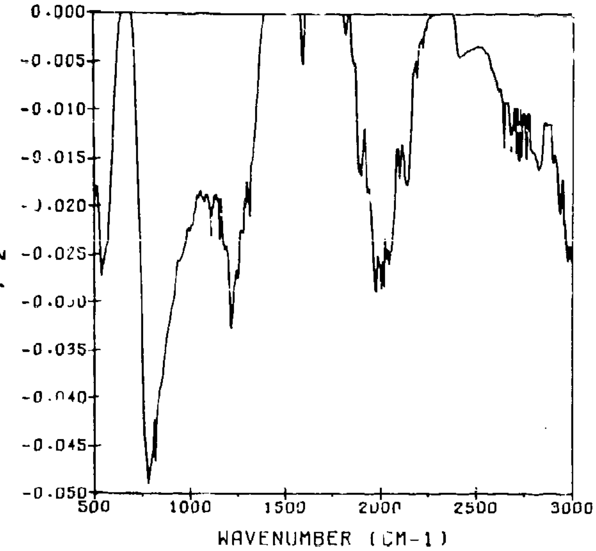

Figure 48. Partial Derivative of the Total Transmittance for the Case in Figure 47 With Respect to the Water Vapor Density

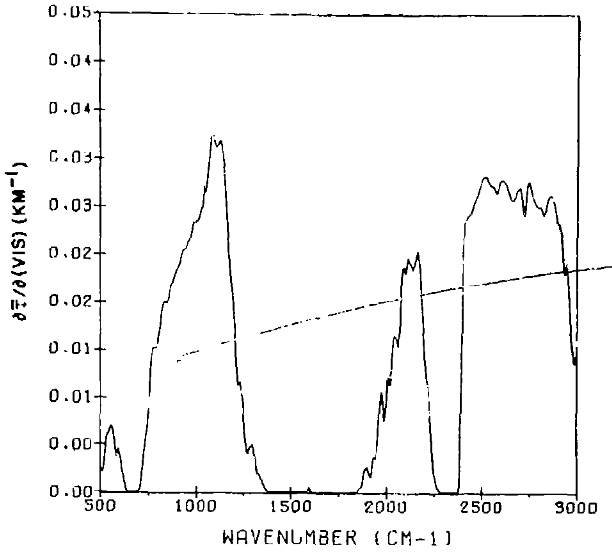

Figure 49. Partial Derivative of the Total Transmittance for the Case in Figure 47 With Respect to VIS

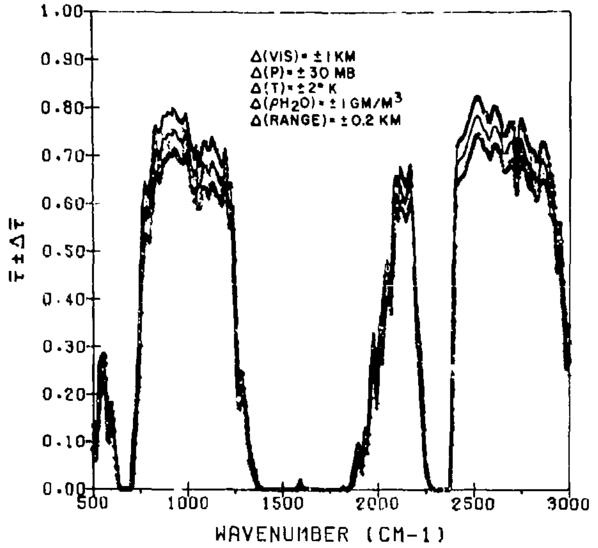

Figure 50. Total Transmittance for the Case in Figure 47 Plus and Minus the RMS Deviation for the Variation in the Meteorological Input Parameters Shown on the Figure

The variation in the total transmittance is shown in Figure 50. Uncertainties in five input parameters (pressure, temperature, meteorological range, water-vapor density, and path length) were assumed for this atmospheric path. For the values used, transmittances varied by approximately ±5 percent in the window regions (1000 and 2500 cm^{-1}).

13. COMMENTS

It should be remembered that the transmittance and radiance values obtained from LOWTRAN are at a spectral resolution of 20 cm^{-1}, although the output can be obtained at 5-cm^{-1} intervals.

The program will round off input frequencies to the nearest frequency at which spectral data are given.

The overall accuracy in transmittance, which this technique provides, is better than 10 percent. The largest errors may occur in the distant wings of strongly absorbing bands in regions which such bands overlap appreciably.

The reason for this error is twofold. First, the spectral curves in Figures 19 to 21, Section 5 are based on a single absorber parameter and cannot be defined for a wide range of atmospheric paths without some loss in accuracy.

Secondly, the transmittance in the window regions between strong bands generally lies in the weak-line approximation region, where the transmittance is a function of the quantity of absorber present and not of the product of absorber amount and pressure. The one-dimensional prediction scheme presented in this report is less accurate for such conditions. The digitized data were obtained for conditions representative of moderate atmospheric paths and will tend to overestimate the transmittance for very long paths and underestimate the transmittance for very short paths, in the spectral regions described above.

As the transmittance approaches 1.0, the percentage error in transmittance decreases toward zero but the uncertainty in the absorption (or radiance) increases.

Additional constraints on both the validity of the model as well as the range of applicability are introduced for atmospheric radiance calculations. As mentioned above the atmospheric radiance becomes less accurate for very short paths. In addition, the radiance calculations assume local thermodynamic equilibrium exists in each layer of the model atmospheres. This assumption will break down for radiance calculations in the upper atmosphere. Therefore, because of the limitations in the LOWTRAN model for short paths (or small absorber amounts) and deviations from thermal equilibrium (both conditions which occur in the upper atmosphere) it is recommended that the LOWTRAN radiance calculations be restricted to altitudes below 40 km.

For the shorter wavelengths (<5 μm), scattered solar radiati n becomes an important source of background radiation. Since this is not included in the LOWTRAN model at the present time, radiance calculations at the shorter wavelengths with a sunlit atmosphere should be made with caution. A single scattering solar-radiance code (SPOT) for plane-parallel geometry has been developed by Lampley and Blattner.[84] This code uses LOWTRAN 4 for the atmospheric attenuation of the solar flux.

Because of the nature of the program — which uses a layered atmosphere — errors can be introduced into the refraction calculation, since we assume each layer to have a mean refractive index associated with it. This is particularly true for a long path in one layer near ground level where one would expect refraction to be a maximum; but in fact, for such a condition the program may indicate no refraction at all. If problems like these are encountered, the number of levels must be increased in the altitude region of interest.

An additional note should be made here on the calculation of transmittance. Although the code will calculate total transmittance for a given atmospheric path in either mode of program execution, the time is increased by a factor of N in the radiance mode, where N is the number of atmospheric layers along a given path.

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Appendix A

Listing of Program

A listing of the Fortran program LOWTRAN 5 (PROGRAM LOWEM) is given in Table A1 together with the 19 subroutines, as described in Section 7 and summarized in Table A2. A definition of symbols used in the main program is given in Appendix B. A segmented loader map of the LOWTRAN 5 code, from the AFGL CDC 6600, is listed in Appendix C. An additional subroutine (DRYSTR), used to generate "dry" stratospheric water vapor profiles is described in Appendix E.

Table A1. Listing of Fortran Code LOWTRAN 5

```
      PROGRAM LOWSM(INPUT=128,OUTPUT=128,TAPE6=OUTPUT,TAPE7=64)
C*****************************************************************
C     LOWTRAN      1 NOV 79
C
*              AUTHORS
*              F.X.KNEIZYS
*              E. P. SHETTLE
*              L. W. ABREU
*              J. H. CHETWYND JR.
*              J.E.A. SELBY
*              W. C. GALLERY
*              R. W. FENN
*              R. A. MCCLATCHEY
C
C     PROGRAM LOWTRAN CALCULATES THE TRANSMITTANCE    AND/OR RADIANCE
C     OF THE ATMOSPHERE
C     FROM 350 CM-1 TO 40000 CM-1 (0.25 TO 28.57 MICRONS) AT 20 CM-1
C     SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.
C     REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.     ATMOSPHERE
C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER-
C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM.
C     INTERVAL TO 100 KM.
C*****************************************************************
C
C     THE FOLLOWING CARDS SHOULD BE KEYPUNCHED BY THE USER
C     AND MAILED TO: F.X.KNEIZYS,AFGL/OPI,HANSCOM AFB,MASS 01731
C     THE CARDS WILL BE USED TO UPDATE THE AFGL MALING LIST
C     AND FOR NOTIFICATION TO THE USER OF ERRORS IN THE CODE
C
C
C            (USE COLUMNS 21 TO 72)
C     LOWT5     NAME
C     LOWT5 COMPANY
C     LOWT5 ADDRESS
C
C
C*****************************************************************
C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS
C
C     CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND,
C     1ISEASN,IVULCN,VIS
C                                    FORMAT(11I3,2F10.3,2I3,F10.3)
C     CARD 2 H1,H2,ANGLE,RANGE,BETA                    FORMAT(7F10.3)
C     CARD 3 V1, V2, DV                                FORMAT(7F10.3)
C     CARD 4 IXY                                       FORMAT(I3)
C
C     MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE
C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,
C     SUBARCTIC WINTER,OR THE 1962 U.S. STANDARD RESPECTIVELY
C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED\INSTEAD OF CARD 2
C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSIT
C     (GM,M-3),O3 DENSITY(GM,M-3), RANGE(KM) WITH FORMAT 429.
C     MODEL=7 WHEN NEW MODEL ATMOSPHERE(E.G. RADIOSONDE DATA) USED.
C     DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN\
C     ALTITUDE(KM.),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY,
C     O3 DENSITY,AEROSOL NO  DENSITY      ,VIS1,IHA1,ISEA1,IVUL1  FORMAT
C     435  SEE NSMDL FOR DETAILS.
C     NOTE THAT EITHER DEW PT. TEMP.OR REL. HUMIDITY CAN BE USED.
C
C     M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.
```

```
C        IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE
C        TBOUND=TEMPERATURE OF EARTH IN DEGREES KELVIN
C        IF TBOUND = ZERO, ASSUMES AIR TEMPERATURE OF MODEL ATMOS.
C
C      IF IHAZE=0 NO AEROSOL EXTINCTION IS COMPUTED
CCC    VIS PARAMETER ON CARD 1 OVERRIDES DEFAULT IHAZE VALUE
CCC    NOTE EXPANSION OF IHAZE PARAMETER
C      IHAZE=1  RURAL-23KM
C      IHAZE=2  RURAL- 5KM
C      IHAZE=3  MARITIME-23KM
C      IHAZE=4 MARITIME-5KM
C      IHAZE=5 URBAN-5KM
C      IHAZE=6 TROPOSPHERIC-50KM
C      IHAZE=7  USER DEFINED
C      IHAZE=8 FOG1 - DEFAULT VISIBILITY =0.2KM
C      IHAZE=9 FOG2 - DEFAULT VISIBILITY =0.5KM
C      VISIBILITY PROFILES  (NEW PARAMETER-ISEASN)
C      ISEASN=0  DEFAULTS TO SEASON OF MODEL
C      ISEASN=1 SPRING-SUMMER
C      ISEASN=2  FALL-WINTER
C      NEW PARAMETER - IVULCN
C               10-30KM AEROSOL TYPE/VIS PROFILE
C      IVULCN=0  DEFAULT TO STRATOSPHERIC BACKGROUND
C      IVULCN=1  STRATOSPHERIC BACKGROUND
C      IVULCN=2  AGED VOLCANIC TYPE/MODERATE VOLCANIC PROFILE
C      IVULCN=3  FRESH VOLCANIC TYPE/HIGH VOLCANIC PROFILE
C      IVULCN=4  AGED VOLCANIC TYPE/HIGH VOLCANIC PROFILE
C      IVULCN=5  FRESH VOLCANIC TYPE/MODERATE VOLCANIC PROFILE
C
C      ITYPE=1,2  OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH
C      ITYPE=3,VERTICAL OR SLANT PATH TO SPACE
C      ITYPE=2,VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES
C      ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH
C
C      H1=OBSERVER ALTITUDE (KM)
C      H2=SOURCE  ALTITUDE (KM)
C      ANGLE= ZENITH ANGLE AT H1 (DEGREES)
C      RANGE=PATH LENGTH (KM)
C      BETA=EARTH CENTRE ANGLE
C      VIS = VISUAL RANGE AT SEA LEVEL (KM)
C      (IF ITYPE=1 READ H1 AND RANGE;IF ITYPE=3 READ H1 AND ANGLE.
C      IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)
C
C      V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE
C      V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE
C      DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED
C      NOTE  DV MUST BE A MULTIPLE OF 5 CM-1
C
C      IXY=0  TO END DATA ,=1 FOR NEW V1,V2,DV ONLY , =2 TO CONTINUE DATA
C      IXY=3 FOR NEW CARD 2 ONLY,=4 FOR NEW CARD 1 ONLY.
C      ******************************************************************
       COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
      1 ,TBOUND,ISEASN,IVULCN,VIS
       COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
       COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,AI
       COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NF1
      1,IFIND,NL,IKLO
       COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
      * ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
       COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
```

```
      COMMON WLAY(74,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      IXY=0
      CALL MD1A
      KMAX=15
      PI=2.0*ASIN(1.0)
      CA=PI/180.
   10 CONTINUE
      RE=6371.23
      IFIND=0
C     JP NE 0  SUPPRESS PRINT
      READ 105, MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
     1,ISEASN,IVULCN,VIS
C     IEMISS=0=TRANSMISSION MODE  / IEMISS=1=EMISSION MODE
      IF (IEMISS.EQ.1) PRINT 110
      IF (IEMISS.EQ.0) PRINT 115
      LENST=LEN
      PRINT 105, MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUN
     1D,ISEASN,IVULCN,VIS
   15 M=MODEL
      IF((M.EQ.3.OR.M.EQ.5).AND.ISEASN.EQ.0) ISEASN=2
      IF (VIS.LE.0.0.AND.IHAZE.GT.0) VIS=VSB(IHAZE)
      ICH(1)=IHAZE
      ICH(2)=6
      ICH(3)=9+IVULCN
      ICH(4)=15
      IF (ICH(1).LE.0) ICH(1)=1
      IF (ICH(3).LE.9) ICH(3)=10
      IF (MODEL.EQ.1) RE=6378.39
      IF (MODEL.EQ.4) RE=6356.91
      IF (MODEL.EQ.5) RE=6356.91
      IF (IHAZE.NE.7) GO TO 20
      READ 200, (DUMMY,EXTC(1,I),ABSC(1,I),I=1,40)
   20 IF (RO.GT.0.0) RE=RO
      IF (MODEL.EQ.7.AND.IM.NE.0) GO TO 35
      IF (IXY.GT.3) GO TO 65
      IF (MODEL.EQ.0) GO TO 35
   25 READ 120, H1,H2,ANGLE,RANGE,BETA
      PRINT 195, H1,H2,ANGLE,RANGE,BETA
      X1=RE+H1
      IF (ITYPE.EQ.3) GO TO 40
      IF (ITYPE.EQ.1) GO TO 65
      X2=RE+H2
      IF (RANGE.EQ.0.) GO TO 50
      PRINT 195, H1,H2,ANGLE,RANGE,BETA
      IF (H2.EQ.0.0.AND.ANGLE.NE.0.0) GO TO 30
      ANGLE=ACOS((.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA
      GO TO 60
   30 X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)
      H2=X2-RE
      GO TO 60
   35 CONTINUE
      IF (ML.LE.0) ML=1
      CALL NSMDL
      IM=0
      IF (MODEL.EQ.0) GO TO 65
      NL=ML
C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD
C     MODEL ATMOSPHERES
      IF (IXY.GT.3) GO TO 65
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      GO TO 25
   40 IF (RANGE.GT.0.0) GO TO 45
      IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1
      GO TO 65
   45 ITYPE=2
      BETA=ACOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA
   50 IF (BETA.EQ.0.) GO TO 55
      IFIND=1
      BET=CA*BETA
      X2=RE+H2
      ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA
      RANGE=X2*SIN(BET)/SIN(ANGLE*CA)
      BET=BETA
      GO TO 65
   55 RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2
      IF (RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))
   60 IF (ANGLE.NE.0..OR.ANGLE.NE.180.) BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)
      IF(ANGLE.LT.0.) ANGLE=ANGLE+180.
      IF (RANGE.LT.0.0) RANGE=-RANGE
      BET=BET/CA
      PRINT 195, H1,H2,ANGLE,RANGE,BET
   65 CONTINUE
      IF (IXY.LE.2) READ 120, V1,V2,DV
      IF (IXY.LE.2) PRINT 120, V1,V2,DV
      IF (ITYPE.EQ.1) PRINT 125, H1,RANGE
      IF (ITYPE.EQ.2) PRINT 130, H1,H2,ANGLE
      IF (ITYPE.EQ.3) PRINT 135, H1,ANGLE
      IF (MODEL.EQ.0) M=7
      IF (VIS.GT.0.0) PRINT 175, VIS
      IF (M.EQ.1) PRINT 140, MODEL
      IF (M.EQ.2) PRINT 145, MODEL
      IF (M.EQ.3) PRINT 150, MODEL
      IF (M.EQ.4) PRINT 155, MODEL
      IF (M.EQ.5) PRINT 165, MODEL
      IF (M.EQ.6) PRINT 160, MODEL
      IF (IHAZE.EQ.0) PRINT 190
      IF (IHAZE.NE.0) PRINT 170, IHAZE,HZ(IHAZE),VIS
      IF (ISEASN.EQ.0) PRINT 205, SEASN(1)
      IF (ISEASN.NE.0) PRINT 205, SEASN(ISEASN)
      IF (IVULCN.EQ.0) PRINT 210, VULCN(1)
      IF (IVULCN.NE.0) PRINT 210, VULCN(IVULCN)
      AVW=10000./V1
      ALAM=10000./V2
      PRINT 180, V1,V2,DV,ALAM,AVW
      CALL HPROF
      CALL GEO
      CALL EXABIN
70    WRITE(7,105)MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,
     1 TBOUND,ISEASN,IVULCN,VIS
      WRITE(7,120) H1,H2,ANGLE,RANGE,BETA
      WRITE(7,120)V1,V2,DV
      IF (IEMISS.EQ.0) GO TO 75
      CALL PATH
      PRINT 215
      PRINT 220
   75 CALL TRANS
      READ 105, IXY
      END FILE 7
      JEXTRA=0
      IFIND=0
```

```
      PRINT 105, IXY                                                    LOW 2410
      IF (IXY.EQ.0) GO TO 95                                            LOW 2420
      GO TO (80,10,85,10,95), IXY                                       LOW 2430
   80 READ 120, V1,V2,DV                                                LOW 2440
      AVW=10000./V1                                                     LOW 2450
      ALAM=10000./V2                                                    LOW 2460
      PRINT 180, V1,V2,DV,ALAM,AVW                                      LOW 2470
      GO TO 70                                                          LOW 2480
   85 IF (IEMISS.EQ.1) PRINT 110                                        LOW 2490
      IF (IEMISS.EQ.0) PRINT 115                                        LOW 2500
      IF (MODEL.EQ.0) GO TO 35                                          LOW 2510
      GO TO 25                                                          LOW 2520
   95 STOP                                                              LOW 2530
C                                                                       LOW 2540
  100 FORMAT (3I5,6F11.4)                                               LOW 2550
  105 FORMAT (11I3,2F10.3,2I3,F11.3)                                    LOW 2560
  110 FORMAT (47H1 PROGRAM WILL BE EXECUTED IN THE EMISSION MODE)       LOW 2570
  115 FORMAT (51H1 PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE)   LOW 2580
  120 FORMAT (7F10.3)                                                   LOW 2590
  125 FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,LOW 2600
     1F7.3,3H KM)                                                       LOW 2610
  130 FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 LOW 2620
     1=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)     LOW 2630
  135 FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H LOW 2640
     1KM, ZENITH ANGLE =,F7.3,8H DEGREES)                               LOW 2650
  140 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)             LOW 2660
  145 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)   LOW 2670
  150 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)   LOW 2680
  155 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )   LOW 2690
  160 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )   LOW 2700
  165 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )   LOW 2710
  170 FORMAT (/20X,15H   HAZE MODEL  ,I1,3H - ,A10,9H    VIS=,F5.1,2HKM)LOW 2720
  175 FORMAT (/25X,13HHAZE MODEL  =,F5.1,29H KM VISUAL RANGE AT SEA LEVELOW 2730
     1L)                                                                LOW 2740
  180 FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1LOW 2750
     14H CM-1 FOR DV =,F6.1,9H CM-1   (,F6.2,3H - ,F5.2,10H MICRONS )) LOW 2760
  185 FORMAT (10X,7F10.3)                                               LOW 2770
  190 FORMAT (/20X,39HAEROSOL SCATTERING NOT COMPUTED,IHAZE=0)          LOW 2780
  195 FORMAT (10X,4H H1=,F7.3,6HKM,H2=,F7.3,9HKM,ANGLE=,F8.4,13HGEOM. RALOW 2790
     1NGE =,F7.2,8HKM,BETA=,F8.5)                                       LOW 2800
  200 FORMAT (4(F6.2,2F7.5))                                            LOW 2810
  205 FORMAT (/20X,10H SEASON = ,A13)                                   LOW 2820
  210 FORMAT (/20X,34H VERTICAL PROFILE AEROSOL MODEL = ,A16)           LOW 2830
  215 FORMAT (1H1,50X,33HRADIANCE(WATTS/CM2-STER-XXX))                  LOW 2840
  220 FORMAT (30X,47HFR(CM-1)  WVL(MICRON)     PER CM-1   PER MICRON,26HLOW 2850
     1     INTEGRAL         TRANS)                                      LOW 2860
      END                                                               LOW 2870
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE MDTA
C
C     MODEL ATMOSPHERE DATA
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      DATA IATM/   6/,N./  34/
      DATA( Z(I),I=1, 34)/
     1    0.,     1.,     2.,     3.,     4.,     5.,     6.,     7.,     8.,
     2    9.,    10.,    11.,    12.,    13.,    14.,    15.,    16.,    17.,
     3   18.,    19.,    20.,    21.,    22.,    23.,    24.,    25.,    30.,
     4   35.,    40.,    45.,    50.,    70.,   100.,99999./
      DATA( P(1,I),I=1, 34)/
     1 1.013E+03, 9.040E+02, 8.050E+02, 7.150E+02, 6.330E+02, 5.590E+02,
     2 4.920E+02, 4.320E+02, 3.780E+02, 3.290E+02, 2.860E+02, 2.470E+02,
     3 2.130E+02, 1.820E+02, 1.560E+02, 1.320E+02, 1.110E+02, 9.370E+01,
     4 7.890E+01, 6.660E+01, 5.550E+01, 4.800E+01, 4.090E+01, 3.500E+01,
     5 3.000E+01, 2.570E+01, 1.220E+01, 6.000E+00, 3.050E+00, 1.590E+00,
     6 8.540E-01, 5.790E-02, 3.000E-04, 0.        /
      DATA( P(2,I),I=1, 34)/
     1 1.013E+03, 9.020E+02, 8.020E+02, 7.100E+02, 6.280E+02, 5.540E+02,
     2 4.870E+02, 4.260E+02, 3.720E+02, 3.240E+02, 2.810E+02, 2.430E+02,
     3 2.090E+02, 1.790E+02, 1.530E+02, 1.300E+02, 1.110E+02, 9.500E+01,
     4 8.120E+01, 6.950E+01, 5.950E+01, 5.100E+01, 4.370E+01, 3.760E+01,
     5 3.220E+01, 2.770E+01, 1.320E+01, 6.520E+00, 3.330E+00, 1.760E+00,
     6 9.510E-01, 6.710E-02, 3.000E-04, 0.        /
      DATA( P(3,I),I=1, 34)/
     1 1.018E+03, 8.973E+02, 7.897E+02, 6.938E+02, 6.081E+02, 5.313E+02,
     2 4.627E+02, 4.016E+02, 3.473E+02, 2.992E+02, 2.568E+02, 2.199E+02,
     3 1.882E+02, 1.610E+02, 1.378E+02, 1.178E+02, 1.007E+02, 8.610E+01,
     4 7.350E+01, 6.280E+01, 5.370E+01, 4.580E+01, 3.910E+01, 3.340E+01,
     5 2.860E+01, 2.430E+01, 1.110E+01, 5.180E+00, 2.530E+00, 1.290E+00,
     6 6.820E-01, 4.670E-02, 3.000E-04, 0.        /
      DATA( P(4,I),I=1, 34)/
     1 1.010E+03, 8.960E+02, 7.929E+02, 7.000E+02, 6.160E+02, 5.410E+02,
     2 4.730E+02, 4.130E+02, 3.590E+02, 3.107E+02, 2.677E+02, 2.300E+02,
     3 1.977E+02, 1.700E+02, 1.460E+02, 1.250E+02, 1.080E+02, 9.280E+01,
     4 7.980E+01, 6.860E+01, 5.890E+01, 5.070E+01, 4.360E+01, 3.750E+01,
     5 3.227E+01, 2.780E+01, 1.340E+01, 6.610E+00, 3.400E+00, 1.810E+00,
     6 9.870E-01, 7.070E-02, 3.000E-04, 0.        /
      DATA( P(5,I),I=1, 34)/
     1 1.013E+03, 8.878E+02, 7.775E+02, 6.798E+02, 5.932E+02, 5.158E+02,
     2 4.467E+02, 3.853E+02, 3.308E+02, 2.829E+02, 2.418E+02, 2.067E+02,
     3 1.766E+02, 1.510E+02, 1.291E+02, 1.103E+02, 9.431E+01, 8.058E+01,
     4 6.882E+01, 5.875E+01, 5.014E+01, 4.277E+01, 3.647E+01, 3.109E+01,
     5 2.649E+01, 2.256E+01, 1.020E+01, 4.701E+00, 2.243E+00, 1.113E+00,
     6 5.719E-01, 4.016E-02, 3.000E-04, 0.        /
      DATA( P(6,I),I=1, 34)/
     1 1.013E+03, 8.986E+02, 7.950E+02, 7.012E+02, 6.166E+02, 5.405E+02,
     2 4.722E+02, 4.111E+02, 3.565E+02, 3.080E+02, 2.650E+02, 2.270E+02,
     3 1.940E+02, 1.658E+02, 1.417E+02, 1.211E+02, 1.035E+02, 8.850E+01,
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     4 7.565E+01, 6.467E+01, 5.529E+01, 4.729E+01, 4.047E+01, 3.467E+01,MDT  610
     5 2.972E+01, 2.549E+01, 1.197E+01, 5.746E+00, 2.871E+00, 1.491E+00,MDT  620
     6 7.978E-01, 5.520E-02, 3.008E-04, 0.        /                      MDT  630
      DATA( T(1,I),I=1, 34)/                                            MDT  640
     1 3.000E+02, 2.940E+02, 2.880E+02, 2.840E+02, 2.770E+02, 2.700E+02,MDT  650
     2 2.640E+02, 2.570E+02, 2.500E+02, 2.440E+02, 2.370E+02, 2.300E+02,MDT  660
     3 2.240E+02, 2.170E+02, 2.100E+02, 2.040E+02, 1.970E+02, 1.950E+02,MDT  670
     4 1.990E+02, 2.030E+02, 2.070E+02, 2.110E+02, 2.150E+02, 2.170E+02,MDT  680
     5 2.190E+02, 2.210E+02, 2.320E+02, 2.430E+02, 2.540E+02, 2.650E+02,MDT  690
     6 2.700E+02, 2.190E+02, 2.100E+02, 2.100E+02/                      MDT  700
      DATA( T(2,I),I=1, 34)/                                            MDT  710
     1 2.940E+02, 2.900E+02, 2.850E+02, 2.790E+02, 2.730E+02, 2.670E+02,MDT  720
     2 2.610E+02, 2.550E+02, 2.480E+02, 2.420E+02, 2.350E+02, 2.290E+02,MDT  730
     3 2.220E+02, 2.160E+02, 2.160E+02, 2.160E+02, 2.160E+02, 2.160E+02,MDT  740
     4 2.160E+02, 2.170E+02, 2.180E+02, 2.190E+02, 2.200E+02, 2.220E+02,MDT  750
     5 2.230E+02, 2.240E+02, 2.340E+02, 2.450E+02, 2.580E+02, 2.700E+02,MDT  760
     6 2.760E+02, 2.180E+02, 2.100E+02, 2.100E+02/                      MDT  770
      DATA( T(3,I),I=1, 34)/                                            MDT  780
     1 2.722E+02, 2.687E+02, 2.652E+02, 2.617E+02, 2.557E+02, 2.497E+02,MDT  790
     2 2.437E+02, 2.377E+02, 2.317E+02, 2.257E+02, 2.197E+02, 2.192E+02,MDT  800
     3 2.187E+02, 2.182E+02, 2.177E+02, 2.172E+02, 2.167E+02, 2.162E+02,MDT  810
     4 2.157E+02, 2.152E+02, 2.152E+02, 2.152E+02, 2.152E+02, 2.152E+02,MDT  820
     5 2.152E+02, 2.152E+02, 2.174E+02, 2.278E+02, 2.432E+02, 2.585E+02,MDT  830
     6 2.657E+02, 2.307E+02, 2.102E+02, 2.100E+02/                      MDT  840
      DATA( T(4,I),I=1, 34)/                                            MDT  850
     1 2.870E+02, 2.820E+02, 2.760E+02, 2.710E+02, 2.660E+02, 2.600E+02,MDT  860
     2 2.530E+02, 2.460E+02, 2.390E+02, 2.320E+02, 2.250E+02, 2.250E+02,MDT  870
     3 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02,MDT  880
     4 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02,MDT  890
     5 2.260E+02, 2.280E+02, 2.350E+02, 2.470E+02, 2.620E+02, 2.740E+02,MDT  900
     6 2.770E+02, 2.160E+02, 2.100E+02, 2.100E+02/                      MDT  910
      DATA( T(5,I),I=1, 34)/                                            MDT  920
     1 2.571E+02, 2.591E+02, 2.559E+02, 2.527E+02, 2.477E+02, 2.409E+02,MDT  930
     2 2.341E+02, 2.273E+02, 2.206E+02, 2.172E+02, 2.172E+02, 2.172E+02,MDT  940
     3 2.172E+02, 2.172E+02, 2.172E+02, 2.172E+02, 2.166E+02, 2.160E+02,MDT  950
     4 2.154E+02, 2.148E+02, 2.141E+02, 2.136E+02, 2.130E+02, 2.124E+02,MDT  960
     5 2.118E+02, 2.112E+02, 2.160E+02, 2.222E+02, 2.347E+02, 2.470E+02,MDT  970
     6 2.593E+02, 2.457E+02, 2.100E+02, 2.100E+02/                      MDT  980
      DATA( T(6,I),I=1, 34)/                                            MDT  990
     1 2.881E+02, 2.816E+02, 2.751E+02, 2.687E+02, 2.622E+02, 2.557E+02,MDT 1000
     2 2.492E+02, 2.427E+02, 2.362E+02, 2.297E+02, 2.232E+02, 2.168E+02,MDT 1010
     3 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02,MDT 1020
     4 2.166E+02, 2.166E+02, 2.166E+02, 2.176E+02, 2.186E+02, 2.196E+02,MDT 1030
     5 2.206E+02, 2.216E+02, 2.265E+02, 2.365E+02, 2.534E+02, 2.642E+02,MDT 1040
     6 2.706E+02, 2.197E+02, 2.100E+02, 2.100E+02/                      MDT 1050
      DATA(WH(1,I),I=1, 34)/                                            MDT 1060
     1 1.900E+01, 1.300E+01, 9.300E+00, 4.700E+00, 2.200E+00, 1.500E+00,MDT 1070
     2 8.500E-01, 4.700E-01, 2.500E-01, 1.200E-01, 5.000E-02, 1.700E-02,MDT 1080
     3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1090
     4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1100
     5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1110
     6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                      MDT 1120
      DATA(WH(2,I),I=1, 34)/                                            MDT 1130
     1 1.400E+01, 9.300E+00, 5.900E+00, 3.300E+00, 1.900E+00, 1.000E+00,MDT 1140
     2 6.100E-01, 3.700E-01, 2.100E-01, 1.200E-01, 6.400E-02, 2.200E-02,MDT 1150
     3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1160
     4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1170
     5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1180
     6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                      MDT 1190
      DATA(WH(3,I),I=1, 34)/                                            MDT 1200
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1 3.500E+00, 2.500E+00, 1.800E+00, 1.200E+00, 6.600E-01, 3.800E-01,MDT 1210
2 2.100E-01, 8.500E-02, 3.500E-02, 1.600E-02, 7.500E-03, 6.900E-03,MDT 1220
3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1230
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1240
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1250
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                     MDT 1260
 DATA(WH(4,I),I=1, 34)/                                             MDT 1270
1 9.100E+00, 6.000E+00, 4.200E+00, 2.700E+00, 1.700E+00, 1.000E+00,MDT 1280
2 5.400E-01, 2.900E-01, 1.300E-01, 4.200E-02, 1.500E-02, 9.400E-03,MDT 1290
3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1300
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1310
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1320
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                     MDT 1330
 DATA(WH(5,I),I=1, 34)/                                             MDT 1340
1 1.200E+00, 1.200E+00, 9.400E-01, 6.800E-01, 4.100E-01, 2.000E-01,MDT 1350
2 9.800E-02, 5.400E-02, 1.100E-02, 8.400E-03, 5.500E-03, 3.800E-03,MDT 1360
3 2.600E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1370
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1380
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1390
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                     MDT 1400
 DATA(WH(6,I),I=1, 34)/                                             MDT 1410
1 5.900E+00, 4.200E+00, 2.900E+00, 1.800E+00, 1.100E+00, 6.400E-01,MDT 1420
2 3.800E-01, 2.100E-01, 1.200E-01, 4.600E-02, 1.800E-02, 8.200E-03,MDT 1430
3 3.700E-03, 1.800E-03, 8.400E-04, 7.200E-04, 6.100E-04, 5.200E-04,MDT 1440
4 4.400E-04, 4.400E-04, 4.400E-04, 4.800E-04, 5.200E-04, 5.700E-04,MDT 1450
5 6.100E-04, 6.600E-04, 3.800E-04, 1.600E-04, 6.700E-05, 3.200E-05,MDT 1460
6 1.200E-05, 1.500E-07, 1.000E-09, 0.        /                     MDT 1470
 DATA(WO(1,I),I=1, 34)/                                             MDT 1480
1 5.600E-05, 5.600E-05, 5.400E-05, 5.100E-05, 4.700E-05, 4.500E-05,MDT 1490
2 4.300E-05, 4.100E-05, 3.900E-05, 3.900E-05, 3.900E-05, 4.100E-05,MDT 1500
3 4.300E-05, 4.500E-05, 4.500E-05, 4.700E-05, 4.700E-05, 6.900E-05,MDT 1510
4 9.000E-05, 1.400E-04, 1.900E-04, 2.400E-04, 2.800E-04, 3.200E-04,MDT 1520
5 3.400E-04, 3.400E-04, 2.400E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1530
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1540
 DATA(WO(2,I),I=1, 34)/                                             MDT 1550
1 6.000E-05, 6.000E-05, 6.000E-05, 6.200E-05, 6.400E-05, 6.600E-05,MDT 1560
2 6.900E-05, 7.500E-05, 7.900E-05, 8.600E-05, 9.000E-05, 1.100E-04,MDT 1570
3 1.200E-04, 1.500E-04, 1.800E-04, 1.900E-04, 2.100E-04, 2.400E-04,MDT 1580
4 2.800E-04, 3.200E-04, 3.400E-04, 3.600E-04, 3.600E-04, 3.400E-04,MDT 1590
5 3.200E-04, 3.000E-04, 2.000E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1600
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1610
 DATA(WO(3,I),I=1, 34)/                                             MDT 1620
1 6.000E-05, 5.400E-05, 4.900E-05, 4.900E-05, 4.900E-05, 5.800E-05,MDT 1630
2 6.400E-05, 7.700E-05, 9.000E-05, 1.200E-04, 1.600E-04, 2.100E-04,MDT 1640
3 2.600E-04, 3.000E-04, 3.200E-04, 3.400E-04, 3.600E-04, 3.900E-04,MDT 1650
4 4.100E-04, 4.300E-04, 4.500E-04, 4.300E-04, 4.300E-04, 3.900E-04,MDT 1660
5 3.600E-04, 3.400E-04, 1.900E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1670
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1680
 DATA(WO(4,I),I=1, 34)/                                             MDT 1690
1 4.900E-05, 5.400E-05, 5.600E-05, 5.800E-05, 6.000E-05, 6.400E-05,MDT 1700
2 7.100E-05, 7.500E-05, 7.900E-05, 1.100E-04, 1.300E-04, 1.800E-04,MDT 1710
3 2.100E-04, 2.600E-04, 2.800E-04, 3.200E-04, 3.400E-04, 3.900E-04,MDT 1720
4 4.100E-04, 4.100E-04, 3.900E-04, 3.600E-04, 3.200E-04, 3.000E-04,MDT 1730
5 2.800E-04, 2.600E-04, 1.400E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1740
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1750
 DATA(WO(5,I),I=1, 34)/                                             MDT 1760
1 4.100E-05, 4.100E-05, 4.100E-05, 4.300E-05, 4.500E-05, 4.700E-05,MDT 1770
2 4.900E-05, 7.100E-05, 9.000E-05, 1.600E-04, 2.400E-04, 3.200E-04,MDT 1780
3 4.300E-04, 4.700E-04, 4.900E-04, 5.600E-04, 6.200E-04, 6.200E-04,MDT 1790
4 6.200E-04, 6.000E-04, 5.600E-04, 5.100E-04, 4.700E-04, 4.300E-04,MDT 1800
```

```
     5 3.600E-04, 3.200E-04, 1.500E-04, 9.200E-05, 4.100E-05, 1.300E-05,
     6 4.300E-06, 8.600E-08, 4.300E-11, 0.       /
      DATA(HO(6,I),I=1, 34)/
     1 5.400E-05, 5.400E-05, 5.400E-05, 5.000E-05, 4.600E-05, 4.600E-05,
     2 4.500E-05, 4.900E-05, 5.200E-05, 7.100E-05, 9.000E-05, 1.300E-04,
     3 1.600E-04, 1.700E-04, 1.900E-04, 2.100E-04, 2.400E-04, 2.800E-04,
     4 3.200E-04, 3.500E-04, 3.800E-04, 3.800E-04, 3.900E-04, 3.800E-04,
     5 3.600E-04, 3.400E-04, 2.000E-04, 1.100E-04, 4.900E-05, 1.700E-05,
     6 4.000E-06, 8.600E-08, 4.300E-11, 0.       /
C     HMIX(I)=HNO3 VOLUME MIXING RATIOS TIMES E+9 FROM EVANS  PROFILE
      DATA HMIX/9*0.,0.1,0.33,0.8,1.2,1.4,1.6,1.8,1.9,2.0,2.1,2.3,3.0,3.
     17,4.2,5.2,6.0,3.8,2.6,0.22,6*0.0/
      DATA (VSB(KKK),KKK=1,9)/23.,5.,23.,5.,5.,50.,23.,0.2,0.5/
      DATA HZ(1)/10H   RURAL  /,HZ(2)/10H   RURAL  /,
     1HZ(3)/10H MARITIME /,HZ(4)/10H MARITIME /,HZ(5)/10H   URBAN  /,
     2HZ(6)/10HTROPCSPHER/,HZ(7)/10HUSER DEFIN/,HZ(8)/10HFOG1 (ADV)/,
     3HZ(9)/10HFOG2 (RAD)/
     4,HZ(10)/10H BACK STRA/,HZ(11)/10H AGED VOL /,HZ(12)/10HFRESH VOL /
     5 ,HZ(15)/10H MET DUST  /
      DATA SEASN(1)/10HSPRIG SUMM/,SEASN(2)/10HFALL WINTR/
      DATA VULCN(1)/10HSTRAT BKGR/,VULCN(2)/10HAG VO-MDVO/,
     1VULCN(3)/10HFR VO-HIVO/,VULCN(4)/10HAG VO-HIVO/,VULCN(5)/10HFR VO-
     2MDVO/
      HMIX(29)=1.0E-50
      HMIX(9)=HMIX(29)
      HZ(13)=HZ(11)
      HZ(14)=HZ(12)
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE NSMDL
C
C     USED FOR USER DEFINED ATMOSPHERIC MODELS (MODEL=0 OR 7)
C     DEFINES ALTITUDE DEPENDENT VARIABLES Z,P,T,WH,WO AND HAZE
C     LOADS HAZE INTO APPROPRATE EH LOCATION
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,FI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NF1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON HLAY(34,15),HPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A
      RV=4.6150E-3
      T0=273.15
      IC1=1
      N=7
      IF(IVULCN.LE.0) IVULCN=1
      IF(ISEASN.LE.0) ISEASN=1
C     FOR MODEL EQ ZERO
      IHA1=0
      ISEA1=0
      IVUL1=0
      VIS1=0.
      AHAZE=0.
C       END OF MODEL ZERO DEFAULT
      IF (M.NE.0) PRINT 100
      DO 65 K=1,ML
      AHOL=10H
      AHOL1=10H
      AHOL2=10H
      AHOL3=10H
      IF (M.EQ.0) READ 85, H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),RANGE
      IF (M.EQ.0) PRINT 90, H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),RANGE
      IF (M.GT.0) READ 80, Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE,V
     1IS1,IHA1,ISEA1,IVUL1
      IF (M.EQ.0) Z(K)=H1
      PRINT 95, Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE,VIS1,IHA1,IS
     1EA1,IVUL1
C     IHA1  IS IHAZE FOR THIS LAYER
C     ISEA1 IS ISEASN FOR THIS LAYER
C     IVUL1 IS IVULCN FOR THE LAYER
      IF(ISEA1.EQ.0) ISEA1=ISEASN
      IF(IHA1.GT.0.OR.IVUL1.GT.0) GO TO 10
      ITYAER=IHAZE
      IF (Z(K).GT.2.0) ITYAER=6
      IF (Z(K).GT.9.0) ITYAER=IVULCN+9
      IF (Z(K).GT.30.) ITYAER=15
      IHA1=IHAZE
      IVUL1=IVULCN
      GO TO 15
   10 IF(IVUL1.GT.0)ITYAER=IVUL1+9
      IF(IHA1.GT.0) ITYAER=IHA1
      IF(ITYAER.GT.15) ITYAER=15
      IF(IHA1.LE.0) IHA1=IHAZE
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF(IVUL1.LE.0) IVUL1=IVULCN                                       NSM  610
   15 IF (K.EQ.1) GO TO 20                                              NSM  620
      IF(N.EQ.7.AND.ITYAER.EQ.6.AND.Z(K).GT.2.0) GO TO 17               NSM  630
      IF (ITYAER.EQ.ICH(IC1)) GO TO 20                                  NSM  640
17    IC1=IC1+1                                                         NSM  650
      N=IC1+10                                                          NSM  660
      IF (IC1.LE.4) GO TO 20                                            NSM  670
      IC1=4                                                             NSM  680
      N=14                                                              NSM  690
      ITYAER=ICH(IC1)                                                   NSM  700
   20 ICH(IC1)=ITYAER                                                   NSM  710
      J=IFIX(Z(K)+1.0E-5)+1                                             NSM  720
      IF (Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.                           NSM  730
      IF (Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.                          NSM  740
      IF (Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.                          NSM  750
      IF (J.GT.33) J=33                                                 NSM  760
      FAC=Z(K)-FLOAT(J-1)                                               NSM  770
      IF (J.LT.26) GO TO 25                                             NSM  780
      FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.                                 NSM  790
      IF (J.GE.31) FAC=(Z(K)-50.0)/20.                                  NSM  800
      IF (J.GE.32) FAC=(Z(K)-70.0)/30.                                  NSM  810
      IF (FAC.GT.1.0) FAC=1.0                                           NSM  820
   25 L=J+1                                                             NSM  830
      T(7,K)=TMP+T0                                                     NSM  840
      IF (M1.GT.0) P(7,K)=P(M1,J)*(P(M1,L)/P(M1,J))**FAC                NSM  850
      IF (M1.GT.0) T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC                NSM  860
      IF (M2.GT.0) WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC            NSM  870
      IF (WH(7,K).GT.0.0) GO TO 35                                      NSM  880
      IF (RH.GT.0.0) GO TO 30                                           NSM  890
      DPK=T0+DP                                                         NSM  900
      TT=T0/DPK                                                         NSM  910
      WH(7,K)=DPK*F(TT)/T(7,K)                                          NSM  920
      GO TO 35                                                          NSM  930
   30 TA=T0/T(7,K)                                                      NSM  940
      RHSAT=F(TA)                                                       NSM  950
      RHO=.01*RH                                                        NSM  960
      DN=(1.0-(1.0-RHO)*RHSAT*RV*T(7,K)/P(7,K))                         NSM  970
      WH(7,K)=RHSAT*RHO/DN                                              NSM  980
   35 CONTINUE                                                          NSM  990
      IF (M3.GT.0) WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC            NSM 1000
      HSTOR(K)=0.                                                       NSM 1010
      IF (HMIX(J).LE.0.) GO TO 40                                       NSM 1020
      IF (HMIX(L).LE.0.) GO TO 40                                       NSM 1030
      HSTOR(K)=HMIX(J)*(HMIX(L)/HMIX(J))**FAC                           NSM 1040
   40 CONTINUE                                                          NSM 1050
      EH(7,K)=0.                                                        NSM 1060
      EH(12,K)=0.                                                       NSM 1070
      EH(13,K)=0.                                                       NSM 1080
      EH(14,K)=0.                                                       NSM 1090
      EH(15,K)=0.                                                       NSM 1100
      IF(IHAZE.EQ.0) GO TO 60                                           NSM 1110
      IF (VIS1.LE.0.0) VIS1=VIS                                         NSM 1120
      IF (AHAZE.EQ.0.0) GO TO 45                                        NSM 1130
      EH(N,K)=AHAZE                                                     NSM 1140
C     AHAZE IS IN LOWTRAN NUMBER DENSITY UNITS                          NSM 1150
      GO TO 55                                                          NSM 1160
   45 CALL AERPRF (J,VIS1,HAZ1,IHA1,ISEA1,IVUL1,NN)                     NSM 1170
      CALL AERPRF (L,VIS1,HAZ2,IHA1,ISEA1,IVUL1,NN)                     NSM 1180
      HAZE=0.                                                           NSM 1190
      IF ((HAZ1.LE.0.0).OR.(HAZ2.LE.0.0)) GO TO 50                      NSM 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      HAZE=HAZ1*(HAZ2/HAZ1)**FAC
   50 EH(N,K)=HAZE
   55 AHOL=HZ(ITYAER)
      IF (AHAZE.NE.0.) GO TO 60
      IF (Z(K).LE.2.0) AHOL1=HZ(IHA1)
      IF ((Z(K).GT.2.0).AND.(Z(K).LE.30.)) AHOL2=SEASN(ISEA1)
      IF (Z(K).GT.9.0) AHOL3=VULCN(IVUL1)
   60 PRINT 95, Z(K),P(7,K),T(7,K),DP,RH,WH(7,K),WO(7,K),EH(N,K),VIS1,IH
     1A1,ISEA1,IVUL1,ITYAER,AHOL1,AHOL2,AHOL3,AHOL
   65 CONTINUE
      IF (IC1.LT.4) GO TO 75
      IC2=IC1+1
      DO 70 K=IC2,4
   70 ICH(K)=ICH(K-1)
   75 CONTINUE
      RETURN
C
   80 FORMAT (3F10.3,2F5.1,2E10.3,E10.3,F7.3,3I1)
   85 FORMAT (3F10.3,2F5.1,2E10.3,2F10.3)
   90 FORMAT (10X,26HINPUT METEOROLOGICAL DATA\/10X,2HZ=,F7.2,7H KM, P=,
     1F7.2,6H MB,T=,F5.1,15H C, DEW PT.TEMP,F5.1,17H C, REL HUMIDITY=,F5
     2.1,16H %, H2O DENSITY=,1PE9.2,7H GM M-3/10X,15H OZONE DENSITY=,E9.
     32,16H GM M-3,  RANGE=,0PF10.3,4H KM )
   95 FORMAT (3F10.3,2F5.1,3E10.3,F10.3,4I3,4(1X,A10))
  100 FORMAT (24H  MODEL ATMOSPHERE NO. 7,/4X,6HZ (KM),3X,6HP (MB),4X,49
     1HT (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.,30X,15HAEROSOL
     2PROFILE,6X,10HEXTINCTION)
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE HPROF
C                                            REVISED 12 DEC 1979
C     DEFINES THE ATMOSPHERIC DENSITY PROFILE OF THE MOLECULAR AND
C        AEROSOL AMOUNTS FOR THE MODEL SELECTED
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A
      DO 5 I=1,34
      DO 5 J=1,KMAX
    5 WLAY(I,J)=0.
C      RV = H2O GAS CONSTANT
      AVW=0.5E-4*(V1+V2)
      AVW=AVW*AVW
      CO=77.46+.459*AVW
      CW=43.487-0.3473*AVW
      IF(TBOUND.LE.0.AND.(M1.LE.0.OR.M.EQ.7))TBOUND=T(M,1)
      IF(TBOUND.LE.0.AND.M1.GT.0.AND.M.LT.7) TBOUND=T(M1,1)
      IF (JP.EQ.0) PRINT 45
      IF (JP.EQ.0) PRINT 50
      IF (M.LT.7) ML=NL
      RV=4.6150E-3
      DO 25 I=1,ML
      PS=P(M,I)/1013.0
      TS=273.15/T(M,I)
      WTEMP=WH(M,I)
      IF(M1.GT.0.AND.M.LT.7)PS=P(M1,I)/1013.
      IF(M1.GT.0.AND.M.LT.7) TS=273.15/T(M1,I)
      IF(M2.GT.0.AND.M.LT.7) WTEMP=WH(M2,I)
      RELHUM(I)=0.
      IF (Z(I).GT.2.0) GO TO 10
      RHOSTR=(PS*1013.0)*(TS/273.15)/RV
      RELHUM(I)=100.0*(WTEMP/F(TS))*((RHOSTR-F(TS))/  (RHOSTR-WTEMP))
10    D=0.1*WTEMP
      X=PS*TS
      PT=PS*SQRT(TS)
      EH(1,I)=D*PT**0.9
      EH(2,I)=X*PT**0.75
      EH(4,I)=0.8*PT*X
      PPW=4.56E-5*D*273.15/TS
      TS1=(296.0/273.15)*TS
      EH(5,I)=D*PPW*EXP(6.08*(TS1-1.0))+0.002*D*(PS-PPW)
      EH(10,I)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))
      EH(6,I)=X
C     SUBROUTINE AERPRF COMPUTES EH(7,I)
C     EH(7,I)=AERSOL FOR 0-2KM
C     EH(12,I)=AERSOL FOR 2-9KM
C     EH(13,I)=AERSOL FOR 9-30KM
C     EH(14,I)=AERSOL FOR 30-100KM
      IF (M.NE.7) CALL AERPRF (I,VIS,HAZE,IHAZE,ISEASN,IVULCN,N)
      IF (M.EQ.7) GO TO 15
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      EH(7,I)=0.
      EH(12,I)=0.
      EH(13,I)=0.
      EH(14,I)=0.
      EH(15,I)=0.
      EH(N,I)=HAZE
   15 CONTINUE
      EH(15,I)=RELHUM(I)*EH(7,I)
      IF(ICH(1).GT.7)EH(15,I)=RELHUM(I)*EH(12,I)
      EH(8,I)=46.6667*WO(M,I)
      IF (M3.GT.0.AND.M.LT.7) EH(8,I)=46.667*WO(M3,I)
      EH(3,I)=EH(8,I)*PT**0.4
C     EH(11,I)=HNO3 ABSORBER AMOUNT (ATM-CM)/KM
      EH(11,I)=PS*TS*HMIX(I)*1.0E-04
      IF (M.EQ.7) EH(11,I)=PS*TS*HSTOR(I)*1.0E-04
      EH(9,I)=1.0
      REF=1.0E-6*(CO*X*1013.0/273.15-PPW*CW)
      IF (I.EQ.ML) GO TO 20
      P2=P(M,I+1)
      T2=T(M,I+1)
      W2=WH(M,I+1)
      IF(M1.GT.0.AND.M.LT.7) P2=P(M1,I+1)
      IF (M1.GT.0.AND.M.LT.7) T2=T(M1,I+1)
      IF (M2.GT.0.AND.M.LT.7) W2=WH(M2,I+1)
      PPW=4.56E-6*W2*T2
      EH(9,I)=0.5*(REF+1.0E-6*(CO*P2/T2-PPW*CW))
   20 IF (I.EQ.ML) EH(9,I)=0.
      IF (JP.NE.0) GO TO 25
      P1=P(M,I)
      T1=T(M,I)
      IF(M1.GT.0.AND.M.LT.7) P1=P(M1,I)
      IF(M1.GT.0.AND.M.LT.7) T1=T(M1,I)
      PRINT 40, I,Z(I),P1,T1,(EH(K,I),K=1,6),EH(9,I),EH(8,I)
   25 CONTINUE
      IF(JP.EQ.0) WRITE (6,55)
      DO 35 I=1,ML
      IF (JP.NE.0) GO TO 30
      P1=P(M,I)
      T1=T(M,I)
      IF(M1.GT.0.AND.M.LT.7) P1=P(M1,I)
      IF(M1.GT.0.AND.M.LT.7) T1=T(M1,I)
      PRINT 40, I,Z(I),P1,T1,(EH(K,I),K=10,11),EH(7,I),(EH(K,I),K=12,15)
     1,RELHUM(I)
   30 EH(9,I)=EH(9,I)+1.
   35 CONTINUE
      RETURN
C
   40 FORMAT (I4,0PF9.2,F9.3,F9.3,1X,1P8E10.3)
   45 FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)
   50 FORMAT (4H  IC,5X,3HALT,6X,1HP,8X,1HT,8X,3HH2O,6X,4HCO2+,8X,2HO3,8H
     1X,2HN2,5X,8HH2O(10M),4X,4HMOLS,5X,5H(N-1),4X,6HO3(UV))
   55 FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/,4H  IC,5X,3HALT,6X,1HP
     1,8X,1HT,6X,7HH2O(4M),5X,4HHNO3,6X,4HAER1,6X,4HAER2,6X,4HAER3,6X,4H
     2AER4,3X,9H(AER1*RH),5X,2HRH)
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE AERPRF (I,VIS,HAZE,IHAZE,ISEASN,IVULCN,N)
C     WILL COMPUTE HORIZONTAL PROFILES FOR AEROSOLS
      COMMON/PRFDTA/ZHT(34),HZ2K(34,5),FAWI50(34),FAWI23(34),SPSU50(34),
     1SPSU23(34),BASTFW(34),VUMOFW(34),HIVUFW(34),EXVUFW(34),BASTSS(34),
     2VUMOSS(34),HIVUSS(34),EXVUSS(34),UPNATM(34),VUTONO(34),
     3VUTOEX(34),EXUPAT(34)
      DIMENSION VS(5)
      DATA (VS(J),J=1,5)/50.,23.,10.,5.,2./
      HAZE=0.
      CALL PRFDTA
      N=7
      IF (IHAZE.EQ.0) RETURN
      IF (ZHT(I).GT.2.0) GO TO 15
      DO 5 J=2,5
      IF (VIS.GE.VS(J)) GO TO 10
    5 CONTINUE
      J=5
   10 CONST=1./(1./VS(J)-1./VS(J-1))
      HAZE=CONST*((HZ2K(I,J)-HZ2K(I,J-1))/VIS+HZ2K(I,J-1)/VS(J)-HZ2K(I,J
     1)/VS(J-1))
      RETURN
   15 IF (ZHT(I).GT.9.0) GO TO 35
      N=12
      CONST=1./(1./23.-1./50.)
      IF (ISEASN.GT.1) GO TO 25
      IF (VIS.LE.23.) HAZE=SPSU23(I)
      IF (VIS.LE.23.) RETURN
      IF (ZHT(I).GT.4.0) GO TO 20
      HAZE=CONST*((SPSU23(I)-SPSU50(I))/VIS+SPSU50(I)/23.-SPSU23(I)/50.)
      RETURN
   20 HAZE=SPSU50(I)
      RETURN
   25 IF (VIS.LE.23.) HAZE=FAWI23(I)
      IF (VIS.LE.23.) RETURN
      IF (ZHT(I).GT.4.0) GO TO 30
      HAZE=CONST*((FAWI23(I)-FAWI50(I))/VIS+FAWI50(I)/23.-FAWI23(I)/50.)
      RETURN
   30 HAZE=FAWI50(I)
      RETURN
   35 IF (ZHT(I).GT.30.0) GO TO 75
      N=13
      HAZE=BASTSS(I)
      IF (ISEASN.GT.1) GO TO 55
      IF (IVULCN.EQ.0) HAZE=BASTSS(I)
      IF (IVULCN.EQ.0) RETURN
      GO TO (40,45,50,50,45), IVULCN
   40 HAZE=BASTSS(I)
      RETURN
   45 HAZE=VUMOSS(I)
      RETURN
   50 HAZE=HIVUSS(I)
      RETURN
   55 IF (IVULCN.EQ.0) HAZE=BASTFW(I)
      IF (IVULCN.EQ.0) RETURN
      GO TO (60,65,70,70,65), IVULCN
   60 HAZE=BASTFW(I)
      RETURN
   65 HAZE=VUMOFW(I)
      RETURN
   70 HAZE=HIVUFW(I)
      RETURN
   75 N=14
      IF (IVULCN.GT.1) GO TO 80
      HAZE=UPNATM(I)
      RETURN
   80 HAZE=VUTONO(I)
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE PRFDTA
C                                   REVISED 10 JUNE 1980
C     AEROSOL PROFILE DATA
C
      COMMON/PRFDTA/ZHT(34),HZ2K(34,5),FAWI50(34),FAWI23(34),SPSU50(34),
     1SPSU23(34),BASTFW(34),VUMOFW(34),HIVUFW(34),EXVUFW(34),BASTSS(34),
     2VUMOSS(34),HIVUSS(34),EXVUSS(34),UPNATM(34),VUTONO(34),
     3VUTOEX(34),EXUPAT(34)
      DATA(ZHT(I),I=1, 34)/
     *    0.,    1.,    2.,    3.,    4.,    5.,    6.,    7.,    8.,
     *    9.,   10.,   11.,   12.,   13.,   14.,   15.,   16.,   17.,
     *   18.,   19.,   20.,   21.,   22.,   23.,   24.,   25.,   30.,
     *   35.,   40.,   45.,   50.,   70.,  100.,99999./
      DATA ( HZ2K(  1,I) ,I=  1,  5)/
     1 6.62E-02, 1.58E-01, 3.79E-01, 7.70E-01, 1.54E+00/
      DATA ( HZ2K(  2,I) ,I=  1,  5)/
     1 4.15E-02, 9.91E-02, 3.79E-01, 7.70E-01, 1.54E+00/
      DATA ( HZ2K(  3,I) ,I=  1,  5)/
     1 2.60E-02, 6.21E-02, 6.21E-02, 6.21E-02, 6.21E-02/
      DATA(FAWI50(I),I=  4, 10)/
     1 1.14E-02, 6.43E-03, 4.85E-03, 3.54E-03, 2.31E-03, 1.41E-03,
     2 9.80E-04/
      DATA(FAWI23(I),I=  4, 10)/
     1 2.72E-02, 1.20E-02, 4.85E-03, 3.54E-03, 2.31E-03, 1.41E-03,
     2 9.80E-04/
      DATA(SPSU50(I),I=  4, 10)/
     1 1.46E-02, 1.02E-02, 9.31E-03, 7.71E-03, 6.23E-03, 3.37E-03,
     2 1.82E-03/
      DATA(SPSU23(I),I=  4, 10)/
     1 3.46E-02, 1.85E-02, 9.31E-03, 7.71E-03, 6.23E-03, 3.37E-03,
     2 1.82E-03/
      DATA(BASTFW(I),I= 11, 27)/
     1 7.87E-04, 7.14E-04, 6.64E-04, 6.23E-04, 6.45E-04, 6.43E-04,
     2 6.41E-04, 6.00E-04, 5.62E-04, 4.91E-04, 4.23E-04, 3.52E-04,
     3 2.95E-04, 2.42E-04, 1.90E-04, 1.50E-04, 3.32E-05/
      DATA(VUMOFW(I),I= 11, 27)/
     1 1.38E-03, 1.79E-03, 2.21E-03, 2.75E-03, 2.89E-03, 2.92E-03,
     2 2.73E-03, 2.46E-03, 2.10E-03, 1.71E-03, 1.35E-03, 1.09E-03,
     3 8.60E-04, 6.60E-04, 5.15E-04, 4.09E-04, 7.60E-05/
      DATA(HIVUFW(I),I= 11, 27)/
     1 1.71E-03, 2.31E-03, 3.25E-03, 4.52E-03, 6.40E-03, 7.81E-03,
     2 9.42E-03, 1.07E-02, 1.10E-02, 8.60E-03, 5.10E-03, 2.70E-03,
     3 1.46E-03, 8.90E-04, 5.80E-04, 4.09E-04, 7.60E-05/
      DATA(EXVUFW(I),I= 11, 27)/
     1 1.71E-03, 2.31E-03, 3.25E-03, 4.52E-03, 6.40E-03, 1.01E-02,
     2 2.35E-02, 6.10E-02, 1.00E-01, 4.00E-02, 9.15E-03, 3.13E-03,
     3 1.46E-03, 8.90E-04, 5.80E-04, 4.09E-04, 7.60E-05/
      DATA(BASTSS(I),I= 11, 27)/
     1 1.14E-03, 7.99E-04, 6.41E-04, 5.17E-04, 4.42E-04, 3.95E-04,
     2 3.82E-04, 4.25E-04, 5.20E-04, 5.81E-04, [illegible]E-04, 5.02E-04,
     3 4.20E-04, 3.00E-04, 1.98E-04, 1.31E-04, 3.32E-05/
      DATA(VUMOSS(I),I= 11, 27)/
     1 1.85E-03, 2.12E-03, 2.45E-03, 2.80E-03, 2.89E-03, 2.92E-03,
     2 2.73E-03, 2.46E-03, 2.10E-03, 1.71E-03, 1.35E-03, 1.09E-03,
     3 8.60E-04, 6.60E-04, 5.15E-04, 4.09E-04, 7.60E-05/
      DATA(HIVUSS(I),I= 11, 27)/
     1 1.85E-03, 2.12E-03, 2.45E-03, 2.80E-03, 3.60E-03, 5.23E-03,
     2 8.11E-03, 1.20E-02, 1.52E-02, 1.53E-02, 1.17E-02, 7.09E-03,
     3 4.50E-03, 2.40E-03, 1.28E-03, 7.76E-04, 7.60E-05/
      DATA(EXVUSS(I),I= 11, 27)/
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     1 1.85E-03, 2.12E-03, 2.45E-03, 2.80E-03, 3.60E-03, 5.23E-03,
     2 8.11E-03, 1.27E-02, 2.32E-02, 4.85E-02, 1.00E-01, 5.50E-02,
     3 6.10E-03, 2.40E-03, 1.28E-03, 7.76E-04, 7.60E-05/
      DATA(UPNATM(I),I= 27, 34)/
     1 3.32E-05, 1.64E-05, 7.99E-06, 4.01E-06, 2.10E-06, 1.60E-07,
     2 9.31E-10, 0.       /
      DATA(VUTONO(I),I= 27, 34)/
     1 7.60E-05, 2.45E-05, 7.99E-06, 4.01E-06, 2.10E-06, 1.60E-07,
     2 9.31E-10, 0.       /
      DATA(VUTOEX(I),I= 27, 34)/
     1 7.60E-05, 7.20E-05, 6.95E-05, 6.60E-05, 5.04E-05, 1.03E-05,
     2 4.50E-07, 0.       /
      DATA(EXUPAT(I),I= 27, 34)/
     1 3.32E-05, 4.25E-05, 5.59E-05, 6.60E-05, 5.04E-05, 1.03E-05,
     2 4.50E-07, 0.       /
CCC          0-2KM
CCC            HZ2K=5 VIS PROFILES- 50KM,23KM,10KM,5KM,2KM
CCC          >2-9KM
CCC            FAWI50=FALL/WINTER   50KM VIS
CCC            FAWI23=FALL/WINTER    23KM VIS
CCC            SPSU50=SPRING/SUMMER  50KM VIS
CCC            SPSU23=SPRING/SUMMER  23KM VIS
CCC          >9-30KM
CCC            BASTFW=BACKGROUND STRATOSPHERIC   FALL/WINTER
CCC            VUMOFW=MODERATE VOLCANIC          FALL/WINTER
CCC            HIVUFW=HIGH VOLCANIC              FALL/WINTER
CCC            EXVUFW=EXTREME VOLCANIC           FALL/WINTER
CCC            BASTSS,VUMOSS,HIVUSS,EXVUSS=      SPRING/SUMMER
CCC          >30-100KM
CCC            UPNATM=NORMAL UPPER ATMOSPHERIC
CCC            VUTONO=TRANSITION FROM VOLCANIC TO NORMAL
CCC            VUTOEX=TRANSITION FROM VOLCANIC TO EXTREME
CCC            EXUPAT=EXTREME UPPER ATMOSPHERIC
CCC   READ IN AEROSOL MODELS   EXTINCTION AND ABSORPTION COEFFICIENTS
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE GEO
C
C     SPHERICAL GEOMETRY WITH REFRACTION
C     DEFINES ABSORBER AMOUNTS FOR THE ATMOSPHERIC SLANT PATH
C     USED TO SET UP VERTICAL PROFILE ARRAY VH AND DEFINES MATRIX
C     WLAY, FOR USE IN SUBROUTINE PATH
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,I J,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      JSTOP=0
      JEXTRA=0
      IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LENST,M,NL,RE,PI,ML)
      IFIND=0
      LEN=LENST
      IF (ITYPE.EQ.1) GO TO 20
      DO 5 K=1,KMAX
      VH(K)=0.0
    5 CONTINUE
      BETA=0.0
      SR=0.0
      IP=0
C      NOW DEFINE CONSTANT PRESSURE PATH QUANTITES  EH(1-8)
      Y=CA*ANGLE
      SPHI=SIN(Y)
      R1=(RE+H1)*SPHI
      IF (H1.GT.Z(NL)) GO TO 10
      GO TO 20
   10 X=(RE+Z(NL))/(RE+H1)
      IF (SPHI.GT.X) GO TO 15
      H1=Z(NL)
      J1=NL
      SPHI=SPHI/X
      ANGLE=180.0-ASIN(SPHI)/CA
      R1=(RE+H1)*SPHI
      GO TO 20
   15 HMIN=R1-RE
      PRINT 235, HMIN
      GO TO 210
   20 CONTINUE
      IP=1
      X1=H1
      CALL POINT (H1,YN,N,NP1,IP)
      J1=N
      TX1=TX(9)
      DO 25 K=1,KMAX
   25 E(K)=TX(K)
      IF (ITYPE.EQ.1) GO TO 80
      IF (ITYPE.EQ.3) H2=Z(NL)
      IF (ANGLE.GT.90.0) GO TO 90
   30 IF (ANGLE.GT.90.0.AND.NP1.GT.0) J1=J1+1
      J2=NL
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (ITYPE.EQ.3) GO TO 35
      CALL FOINT (H2,YN,N,NP,IP)
      J2=N
      IF (NP.GT.0) J2=J2-1
   35 DO 40 K=1,KMAX
      IF (K.EQ.9) GO TO 40
      EH(K,J1)=F(K)
      IF (ITYPE.EQ.3) GO TO 40
      EH(K,J2+1)=TX(K)
   40 CONTINUE
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH
      IF (JP.EQ.0) PRINT 225
      DO 45 K=1,KMAX
   45 W(K)=0.
      DO 75 I=J1,J2
      X1=Z(I)
      X2=Z(I+1)
      IF (I.EQ.J1) X1=H1
      IF (I.EQ.J2) X2=H2
      DZ=X2-X1
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)
      DS=DZ
C       UPWARD TRAJECTORY
      RX=(RE+X1)/(RE+X2)
      THETA=ASIN(SPHI)/CA
      PHI=ASIN(SPHI*RX)/CA
      BET=THETA-PHI
      SALP=RX*SPHI
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI
      BETA=BETA+BET
      PSI=BETA+PHI-ANGLE
      PHI=180.-PHI
      SR=SR+DS
      JEXTRA=0
      DO 70 K=1,KMAX
      EV=DS*EH(K,I)
      IF (I.EQ.NL) GO TO 50
      IF (EH(K,I).EQ.0.0.OR.EH(K,I+1).EQ.0.0) GO TO 55
      IF (ABS((EH(K,I)/EH(K,I+1))-1.0).LT.1.0E-6) GO TO 60
      EV=DS*(EH(K,I)-EH(K,I+1))/ALOG(EH(K,I)/EH(K,I+1))
      GO TO 60
   50 IF (EH(K,I).EQ.0.0) GO TO 55
      IF (EH(K,I-1).EQ.0.0) GO TO 55
      IF (ABS((EH(K,I-1)/EH(K,I))-1.0).LT.1.0E-6) GO TO 60
      EV=EV/ALOG(EH(K,I-1)/EH(K,I))
      GO TO 60
   55 EV=0.
   60 VH(K)=VH(K)+EV
      IF (I.EQ.JSTOP) GO TO 65
      WLAY(I,K)=EV+W(K)
      W(K)=0.
      GO TO 70
   65 W(K)=EV
      IF (J1.NE.J2) GO TO 70
      WLAY(J2+1,K)=W(K)
      W(K)=0.
      JEXTRA=1
   70 CONTINUE
      IF (JP.EQ.0) PRINT 245, I,X1,(VH(L),L=1,8),PSI,PHI,BETA,THETA,SR
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (JP.EQ.0) PRINT 240, X2,(VH(L),L=10,14),DS
      IF (I.GE.NL) GO TO 75
      IF (I+1.EQ.J2) EH(9,I+1)=YN
      IF (I.EQ.J1) EH(9,I)=TX1
      RN=EH(9,I+1)/EH(9,I)
      SPHI=SPHI*RX/RN
      IF (SALP.GE.RN) SPHI=SALP
   75 CONTINUE
      GO TO 190
C     HORIZONTAL PATH
   80 DO 85 K=1,KMAX
      W(K)=RANGE*EH(K,1)
      IF (M.GT.0) W(K)=RANGE*TX(K)
      VH(K)=W(K)
   85 CONTINUE
      GO TO 200
   90 CONTINUE
C       DOWNWARD TRAJECTORY
      K2=0
      IF (NP1.EQ.1) J1=J1-1
      J2=J1+1
      J=J1+1
      YN1=YN
      IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 100
      IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 100
      CALL POINT (H2,YN,N,NP2,IP)
      DO 95 K=1,KMAX
   95 W(K)=TX(K)
      TX2=TX(9)
      YN2=YN
      IF (H2.LT.H1) H=H2
      J2=N
      IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)
      IF (H2.GT.H1) TX1=TX2
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2
  100 A0=(RE+H1)*SPHI*YN1
      IF (H2.GE.H1) YN2=YN1
      DO 105 I=1,J1
      HMIN=A0/EH(9,I)-RE
      IF (I.EQ.J1) HMIN=A0/YN1-RE
      JMIN=I
      IF (HMIN.LE.Z(I+1)) GO TO 110
  105 CONTINUE
  110 X=HMIN
      IF (HMIN.LE.0.0) GO TO 120
      CALL POINT (X,YN,N,NP,IP)
      JMIN=N
      TX3=TX(9)
      IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)
      IF (TX3.LT.0.0) TX3=TX(9)
      IF (J1.EQ.N.AND.H2.GE.H1) GO TO 115
      HMIN=A0/TX3-RE
      IF (ABS(X-HMIN).GT.0.0001) GO TO 110
  115 IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3
      IF (H2.GE.H1) TX2=TX3
      IF (H2.GE.H1) J2=N
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN
      PRINT 250, HMIN
      IF (H2.LT.HMIN) J2=N
```

```
      IF (H2.LT.HMIN) PRINT 270, HMIN
      GO TO 125
  120 PRINT 250, HMIN
      IF (H2.LT.H1) GO TO 175
      IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 255
      ITYPE=2
      TX2=EH(9,1)
      JMIN=0
      J2=1
      H2=0.0
      H=0.0
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH
  125 IF (JP.EQ.0) PRINT 225
      JSTOR=J-1
      DO 155 I=1,NL
      J=J-1
      REF=EH(9,J)
      IF (I.EQ.1) REF=YN1
      IF (I.EQ.1.AND.K2.EQ.1) REF=YN2
      IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2
      IF (I.NE.1) X1=Z(J+1)
      X2=Z(J)
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN
      HM=(RE+X1)*SPHI-RE
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM
      RX=(RE+X1)/(RE+X2)
      DS=X1-X2
      ALP=90.0
      THET=ASIN(SPHI)/CA
      SALP=RX*SPHI
      IF (ABS(X2-HM).GT.1.0E-5) ALP=ASIN(SALP)/CA
      BET=ALP-THET
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI
      THETA=180.0-THET
      BETA=BETA+BET
      PSI=BETA-ALP-ANGLE+180.0
      SR=SR+DS
      DO 150 K=1,KMAX
      AJ=EH(K,J)
      BJ=EH(K,J+1)
      IF (J.EQ.J1) BJ=E(K)
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=W(K)
      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)
      IF (K2.EQ.0) GO TO 130
      IF (J.EQ.J2) BJ=W(K)
      IF (J.EQ.JMIN) AJ=TX(K)
  130 IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 140
      IF (ABS((AJ/BJ)-1.0).LE.1.0E-6) GO TO 135
      EV=DS*(AJ-BJ)/ALOG(AJ/BJ)
      GO TO 145
  135 EV=DS*AJ
      GO TO 145
  140 EV=0.0
  145 VH(K)=VH(K)+EV
  150 WLAY(J,K)=EV
      IF (JP.EQ.0) PRINT 245, J,X1,(VH(L),L=1,8),PSI,ALP,BETA,THETA,SR
      IF (JP.EQ.0) PRINT 240, X2,(VH(L),L=10,14),DS
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 180
```

```
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 170
      IF (J.NE.1) RN=REF/EH(9,J-1)
      IF (J.EQ.J2+1) RN=REF/TX2
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3
      IF (SALP.GE.RN) RN=1.0
      SPHI=SALP*RN
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 160
  155 CONTINUE
  160 IF (HMIN.LE.0.0) GO TO 190
      IF (LEN.EQ.0) PRINT 260
      IF (LEN.EQ.0) GO TO 190
      IF (LEN.EQ.1) PRINT 265
      K2=1
      X1=X2
      IF (ABS(X1-HMIN).LE.0.001) GO TO 190
      H=HMIN
      J=J2+1
      IF (NP2.EQ.1) J=J-1
      B=BETA
      PH=180.0-ASIN(SPHI)/CA
      TS=SR
      PS=PSI
      DO 165 K=1,KMAX
  165 E(K)=VH(K)
      GO TO 125
  170 BETA=2.*BETA-B
      PSI=2.*PSI-PS
      SR=2.*SR-TS
C       LONG PATH, TAKEN
      PHI=PH
      DO 175 K=1,KMAX
  175 VH(K)=2.*VH(K)-E(K)
      GO TO 190
  180 DO 185 K=1,KMAX
  185 VH(K)=2.0*VH(K)
      BETA=2.0*BETA
      SR=2.0*SR
      IF (H2.EQ.H1) GO TO 190
      RN=TX1/YN1
      SPHI=SIN(ANGLE*CA)
      IF (SPHI.LT.RN) SPHI=SPHI/RN
      GO TO 30
  190 CONTINUE
      IF (ANGLE.GT.90.0) PRINT 215, HM
      DO 195 K=1,KMAX
      W(K)=VH(K)
  195 CONTINUE
  200 WRITE (6,220)
      WRITE (6,280)
      WRITE (6,230) (W(I),I=1,8),W(10),W(11)
      IF(W(7).GT.0.0.AND.ICH(1).LE.7) W(15)=W(15)/W(7)
      IF(W(12).GT.0.0.AND.ICH(1).GT.7) W(15)=W(15)/W(12)
  205 WRITE (6,275) (W(I),I=12,15)
      I=1
  210 RETURN
C
  215 FORMAT (7F10.3)
  220 FORMAT (/10X,38H EQUIVALENT SEA LEVEL ABSORBER AMOUNTS//21X,112H W
     1ATER VAPOUR      CO2 ETC.       OZONE     NITROGEN (CONT)   H2O   (CCN
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
   2T)       MOL   SCAT       AER1         OZONE(U-V)/24X,7HGM CM-2,10X,2HK
   3M,10X,5HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM.11X,5X,10X,6HATM CM)
225 FORMAT (1H1,/10X,20H   VERTICAL PROFILES,//,1X,2HID,3X,3HALT,6X,3HP
   1H20,7X,4HCO2+,6X,2HO3,9X,2HN2,6X,8HH20(10M),4X,4HMOLS,6X,4HAER1,5X
   2,6HO3(UV),5X,3HPSI,6X,3HPHI,6X,4HBETA,4X,5HTHETA,4X,5HRANGE,/,14X,
   35H      ,4X,7HH20(4M),5X,4HHNO3,6X,4HAER2,6X,4HAER3,6X,4HAER4,3X,,5
   48X,6HORANGE//)
230 FORMAT (/10X,8H W(1-8)=8(E14.3)/74X,E14.3,28X,E14.3/)
235 FORMAT (69H TRAJECTORY MISSES EARTHS ATMOSPHERE. CLOSEST DISTANCE 
   1OF APPROACH IS,F10.2,1X,/,1X,18HEND OF CALCULATION)
240 FORMAT (4X,F8.3,10X,1P5E10.3,56X,0PF7.2,/)
245 FORMAT (I4,F8.3,1P8E10.3,0P4F9.4,F7.1)
250 FORMAT (8H HMIN = ,F10.3)
255 FORMAT (64H PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2
   1 = 0.0 KM)
260 FORMAT (84H CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN
   1.  FOR LONGER PATH SET LEN=1.)
265 FORMAT (85H CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.
   1    FOR SHORT PATH SET LEN = 0 )
270 FORMAT (74H H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO 
   1     HMIN I.E. H2 = ,F10.3)
275 FORMAT (/30X,4HAER2,10X,4HAER3,10X,4HAER4,5X,9HR.H. MEAN,/10X,10H
   1W(12-15)=,4(1PE14.3)/)
280 FORMAT (118X,11HNITRIC ACID)
    END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,M,NL,RE,PI,ML)
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TEBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
C     ******************************************************************
C
C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)
C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA
C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),
C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.
C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL
C     ATMOSPHERE.
C
C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.
C     ******************************************************************
      IP=99
      CA=PI/180.
      X1=RE+H1
      X2=RE+H2
      LEN=0.
      IT=0
      B1=B1*CA
      TANG=X2*SIN(B1)/(X2*COS(B1)-X1)
      THET=ATAN(TANG)
      IF (THET.LT.0.0) THET=THET+PI
      SPHI=SIN(THET)
      ANG=THET/CA
      TN=THET
      TH=TN-0.5*CA
    5 ANGLE=THET
      FBT=0.
      BETA=0.
      BET1=0
      BET2=0
      FBT1=0
      FBT2=0
      FBT3=0.0
      IF (B1.LE.0.0) GO TO 10
      Y=2.*THET
      IF (Y-PI.GT.1.0E-8) GO TO 45
      IF (IP.EQ.100) GO TO 30
      XMIN=X2*COS(B1)-RE
      IF (XMIN-H1) 40,20,20
   10 HMIN=H2
      H2=H1
      H1=HMIN
   15 ANGLE=0.5*PI
      THET=ANGLE
      SPHI=1.0
      ANG=ANGLE/CA
   20 IP=100
      CALL POINT (H1,YN,N,NP,IP)
      J1=N
      TX1=TX(9)
   25 CALL POINT (H2,YN,N,NP,IP)
      IF (NP.EQ.1) N=N-1
      J2=N
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
   30 DO 35 J=J1,J2
      X1=RE+Z(J)
      X2=RE+Z(J+1)
      IF (J.EQ.J1) X1=RE+H1
      IF (J.EQ.J2) X2=RE+H2
      SALP=X1*SPHI/X2
      ALP=ASIN(SALP)
      RN=EH(9,J+1)/EH(9,J)
      IF ((J+1).EQ.J2) RN=YN/EH(9,J)
      IF (J.EQ.J1) RN=EH(9,J+1)/TX1
      IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1
      BET=THET-ALP
      FB=-TAN(ALP)
      IF (J.NE.J1) FB=FB+TAN(THET)
      FBT=FBT+FB
      BETA=BETA+BET
      TH1=THET/CA
      BE=BET/CA
      C=ALP/CA
      IF (X2.EQ.RE+H2) C=PI-ALP
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP/RN
      THET=ASIN(SPHI)
   35 CONTINUE
      IF (B1.LE.0.0) GO TO 125
      GO TO 115
   40 CONTINUE
      TANG=-TANG
      ANGLE=PI-ANGLE
      TN=ANGLE
      ANG=ANGLE/CA
      IF (H1.LE.0.0) GO TO 15
   45 CONTINUE
      IP=101
      CALL POINT (H1,YN,N,NP1,IP)
      TX1=TX(9)
      YN1=YN
      IF (NP1.EQ.1) N=N-1
      J2=NL
      IF (M.EQ.7) J2=ML
      J1=N
      J=J1+1
      IF (H2.GE.H1) GO TO 65
      CALL POINT (H2,YN,N,NP,IP)
      TX2=TX(9)
      YN2=YN
      J2=N
      IF (J1.EQ.J2) TX2=YN1+TX(9)-EH(9,J1)
   50 J=J-1
      X1=RE+Z(J+1)
      X2=RE+Z(J)
      IF (J.EQ.J1) X1=RE+H1
      IF (J.EQ.J2) X2=RE+H2
      SALP=X1*SPHI/X2
      HMIN=X1*SPHI-RE
      IF (SALP.LE.1.0) GO TO 55
      SALP=SPHI
      IF (HMIN.GT.H2) GO TO 80
   55 ALP=ASIN(SALP)
      THET=ASIN(SPHI)
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      BET=ALP-THET
      BET1=BET1+BET
      FB=TAN(ALP)
      IF (J.NE.J1) FB=FB-TAN(THET)
      FBT1=FBT1+FB
      TH1=THET/CA
      BE=BET/CA
      AL=ALP/CA
      IF (X2.EQ.RE+H2) C=PI-ALP
      REF=EH(9,J)
      IF (J.EQ.J1) REF=YN1
      IF (J.EQ.J2) REF=TX2
      IF (J.EQ.1) GO TO 60
      RN=EH(9,J)/EH(9,J-1)
      IF (J.EQ.J1) RN=YN1/EH(9,J-1)
      IF (J.EQ.J2+1) RN=REF/TX2
      IF (J.EQ.J2) RN=REF/YN2
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP*RN
      IF (Z(J).LE.H2) GO TO 60
      GO TO 69
   60 X1=X2
      IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 65
      GO TO 70
   65 J=J-1
      X1=RE+Z(J+1)
      IF (J.EQ.J1) X1=RE+H1
      IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2
   70 X2=RE+Z(J)
      HMIN=X1*SPHI-RE
      IF (HMIN.LE.0.0) GO TO 110
      IF (Z(J).LT.HMIN) GO TO 80
      REF=EH(9,J)
      IF (J.EQ.J2) REF=YN
      SALP=X1*SPHI/X2
      ALP=ASIN(SALP)
      THET=ASIN(SPHI)
      BET=ALP-THET
      FB=TAN(ALP)-TAN(THET)
      FBT2=FBT2+FB
      BET2=BET2+BET
      BMIN=BET1+BET2
      AL=ALP/CA
      TH1=THET/CA
      RN=REF/EH(9,J-1)
      IF (SALP.GE.RN) RN=1.0
      SPHI=SALP*RN
      GO TO 65
   75 TX3=YN1+TX(9)-EH(9,J1)
      YN1=TX3
      IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)
      IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)
      RN=1.0
      GO TO 65
   80 CALL POINT (HMIN,YN,N,NF,IP)
      IP=102
      TX3=TX(9)
      IF (J.EQ.J1.AND.H2.GE.H1) GO TO 75
      IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)
      IF (HMIN.GT.H2) TX3=TX(9)
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 75
      RN=REF/TX3
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP*RN
      X=X1*SPHI-RE
      DIF=ABS(HMIN-X)
      HMIN=X
      IF (DIF-1.0E-5) 85,85,80
   85 X2=RE+HMIN
      THET=ASIN(SPHI)
      IF (RN.EQ.1.0) FBT3=-TAN(THET)
      IF (RN.EQ.1.0) GO TO 90
      DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)
      FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))
   90 BET=0.5*PI-THET
      BET2=BET2+BET
      BMIN=BET1+BET2
      IF (H2.GE.H1) GO TO 100
      BET=BET1+2.*BET2
      DB1=B1-BET1
      DB2=BET-B1
      DB3=ABS(BMIN-B1)
      IF (DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 110
      IF (DB2.GT.DB3) GO TO 95
      IF (DB2.GT.DB1) GO TO 110
      BETA=BET
      FBT=FBT1+2.0*(FBT2+FBT3)
      LEN=1.
      GO TO 115
   95 BETA=BET1+BET2
      FBT=FBT1+FBT2+FBT3
      GO TO 115
  100 BETA=2.0*(BET1+BET2)
      LEN=1.
      FBT=2.0*(FBT1+FBT2+FBT3)
      PRINT 130, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1
      IF (H2.EQ.H1) GO TO 115
      IP=103
      IF (NP1.EQ.1) J1=J1+1
      SPHI=SIN(ANGLE)
      IF (Z(J1+1).LE.H2) GO TO 105
      RN=TX1/YN1
      IF (SPHI.GE.RN) RN=1.
      SPHI=SPHI/RN
      THET=ASIN(SPHI)
      GO TO 25
  105 CALL POINT (H2,YN,N,NP,IP)
      TX1=TX1+YN-EH(9,J1)
      RN=TX1/YN1
      J2=J1
      IF (SPHI.GE.RN) RN=1.
      SPHI=SPHI/RN
      THET=ASIN(SPHI)
      GO TO 25
  110 BETA=BET1
      LEN=0.
      FBT=FBT1
  115 THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)
      DBETA=BETA/CA
      B=BET1/CA
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      TH1=THET/CA
      PRINT 135, BETA,DBETA,FBT,TH1,TANG
      IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.
      TH1=THET/CA
      PRINT 135, BET1,B,FBT,TH1
      TN1=TN/CA
      TM1=TM/CA
      PRINT 140, TN,TM,TN1,TM1
      SPHI=SIN(THET)
      TANG=TAN(THET)
      IT=IT+1
      DBE=ABS(B1-BETA)
      DTH=ABS(ANGLE-THET)
      IF (IT.EQ.10) THET=0.5*(ANGLE+THET)
      IF (IT.EQ.10) GO TO 120
      IF (DBE.GT.1.0E-7.AND.DTH.GT.1.0E-7) GO TO 5
  120 ANGLE=THET/CA
      PRINT 145, ANGLE,IT
      RETURN
  125 H1=H2
      ANGLE=C/CA
      PRINT 145, ANGLE,IT
      RETURN
C
  130 FORMAT (I6,F16.7,8F13.8)
  135 FORMAT (14H TOTAL BETA = ,E14.6,F15.6,7H,FBT = ,E14.6,7H THET =,F1
     10.6,5HTANG=,F10.6)
  140 FORMAT (5F12.6)
  145 FORMAT (8X,/1H*,14HZENITH ANGLE =,F7.3,60H DEGREES \  RECOMPUTED
     1    FROM SUBROUTINE ANGL (ITTERATION,I3,1H))
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE FCINT (X,YN,N,NP,IP)
C                                                 REVISED 12 DEC 79
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,JL,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
C     ******************************************************************
C     SUBROUTINE FOINT COMPUTES THE MEAN REFR. INDEX ABOVE AND BELOW
C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE
C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
C
C     ******************************************************************
C
C      X IS THE HEIGHT IN QUESTION
C      TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
C      N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
C      NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0
C      TX(1-8) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X
C     ******************************************************************
      N=NL
      NP=0
      IF (X.LT.0.0) X=Z(1)
      IF (X.GT.Z(NL)) GO TO 20
      DO 5 I=1,NL
      N=I
      IF (X-Z(I)) 10,20,5
    5 CONTINUE
   10 J2=N
      N=N-1
      MM1=M
      IF(M1.GT.0.AND.M.LT.7) MM1=M1
      MM2=M
      IF(M2.GT.0.AND.M.LT.7) MM2=M2
      FAC=(X-Z(N))/(Z(J2)-Z(N))
      PX1=P(MM1,N)*(P(MM1,J2)/P(MM1,N))**FAC
      TX1=T(MM1,N)*(T(MM1,J2)/T(MM1,N))**FAC
      WX1=WH(MM2,N)*(WH(MM2,J2)/WH(MM2,N))**FAC
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CW
      TX(2)=CO*P(MM1,J2)/T(MM1,J2)-4.56E-6*WH(MM2,J2)*T(MM1,J2)*CW
      TX(1)=CO*P(MM1,N)/T(MM1,N)-4.56E-6*WH(MM2,N)*T(MM1,N)*CW
      TX(9)=0.5E-6*(TX(2)+TX(3))
      YN=0.5E-6*(TX(1)+TX(3))
      IF (IP.EQ.0) GO TO 35
      DO 15 K=1,KMAX
      IF (K.EQ.9) GO TO 15
      TX(K)=0.0
      IF (EH(K,N).GT.1000.0) GO TO 15
      IF (X.LE.100.0) TX(K)=EH(K,N)+FAC*(EH(K,J2)-EH(K,N))
      IF (EH(K,N).EQ.0.0.OR.EH(K,J2).EQ.0.0) GO TO 15
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC
   15 CONTINUE
      GO TO 35
   20 NP=1
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (IP.EQ.0) GO TO 30
      DO 25 K=1,KMAX
   25 TX(K)=EH(K,N)
   30 TX(9)=EH(9,N)-1.
      YN=0.0
C        CARDS P 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED
      IF (N.GT.1) YN=EH(9,N-1)-1.0
   35 CONTINUE
      IF (IP.EQ.1) PRINT 45, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)
      IF (IP.EQ.1) PRINT 40, (TX(K),K=12,14)
      TX(9)=TX(9)+1.
      YN=YN+1.
      RETURN
C
   40 FORMAT (//5X,11H TX(12-14)=,3E10.3/)
   45 FORMAT (/,20H FROM POINT\ HEIGHT=,F10.4,6H KM,N=,I3,4H,NP=,I2,28H,
     1REF. INDEX ABOVE & BELOW X=,2E11.4,4H,IP=,I3,/,12X,36HEQUIV. ABSOR
     2BER AMOUNTS PER KM AT X=,5E10.3)
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE EXABIN
C
C      LOADS EXTINCTION AND ABSORPTION COEFFICIENTS FOR THE FOUR
C         AEROSOL ALTITUDE REGIONS
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,MD,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX0(40)
      COMMON /EXTDTA/  VX2(40),RUREXT(40,4),RURABS(40,4),URBEXT(40,4),
     1URBABS(40,4),OCNEXT(40,4),OCNABS(40,4),TROEXT(40,4),TROABS(40,4),
     2FG1EXT(40),FG1ABS(40),FG2EXT(40),FG2ABS(40)
     3,BSTEXT(40),BSTABS(40),AVOEXT(40),AVOABS(40),FVOEXT(40
     4),FVOABS(40),DMEEXT(40),DMEABS(40)
      DIMENSION RHZONE(4)
      DATA (RHZONE(I),I=1,4)/0.,70.,80.,99./
      PRINT 90, (ICH(I),I=1,4)
      CALL EXTDTA
      DO 5 I=1,40
    5 VX0(I)=VX2(I)
      I1=1
      IF (IHAZE.EQ.7) I1=2
      DO 85 M=I1,4
      ITA=ICH(M)
      ITC=ICH(M)-7
      WRH=W(15)
      IF (ICH(M).EQ.6.AND.M.NE.1) WRH=70.
C     THIS CODING  DOES NOT ALLOW TROP RH DEPENDENT  ABOVE EH(7,I)
C     DEFAULTS TO TROPOSPHERIC AT 70. PERCENT
      DO 10 I=2,4
      IF (WRH.LT.RHZONE(I)) GO TO 15
   10 CONTINUE
      I=4
   15 II=I-1
      IF(WRH.GT.0.0.AND.WRH.LT.99.) X=ALOG(100.0-WRH)
      X1=ALOG(100.0-RHZONE(II))
      X2=ALOG(100.0-RHZONE(I))
      IF (WRH.GE.99.0) X=X2
      IF (WRH.LE.0.0) X=X1
      DO 80 N=1,40
      ABSC(M,N)=0.
      EXTC(M,N)=0.
      IF(ITA.GT.6) GO TO 45
      IF(ITA.LE.0) GO TO 80
C     RH DEPENDENT AEROSOLS
      GO TO (20,20,25,25,30,35), ITA
   20 Y2=ALOG(RUREXT(N,I))
      Y1=ALOG(RUREXT(N,II))
      Z2=ALOG(RURABS(N,I))
      Z1=ALOG(RURABS(N,II))
      GO TO 40
   25 Y2=ALOG(OCNEXT(N,I))
      Y1=ALOG(OCNEXT(N,II))
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      Z2=ALOG(OCNABS(N,I))                                           EXA  610
      Z1=ALOG(OCNABS(N,II))                                          EXA  620
      GO TO 40                                                       EXA  630
   30 Y2=ALOG(URBEXT(N,I))                                           EXA  640
      Y1=ALOG(URBEXT(N,II))                                          EXA  650
      Z2=ALOG(URBABS(N,I))                                           EXA  660
      Z1=ALOG(URBABS(N,II))                                          EXA  670
      GO TO 40                                                       EXA  680
   35 Y2=ALOG(TROEXT(N,I))                                           EXA  690
      Y1=ALOG(TROEXT(N,II))                                          EXA  700
      Z2=ALOG(TROABS(N,I))                                           EXA  710
      Z1=ALOG(TROABS(N,II))                                          EXA  720
   40 Y=Y1+(Y2-Y1)*(X-X1)/(X2-X1)                                    EXA  730
      ZK=Z1+(Z2-Z1)*(X-X1)/(X2-X1)                                   EXA  740
      ABSC(M,N)=EXP(ZK)                                              EXA  750
      EXTC(M,N)=EXP(Y)                                               EXA  760
      GO TO 80                                                       EXA  770
   45 IF (ITA.GT.14) GO TO 75                                        EXA  780
      IF (ITC.LT.1) GO TO 80                                         EXA  790
      GO TO (50,55,60,65,70,65,70), ITC                              EXA  800
   50 ABSC(M,N)=FG1ABS(N)                                            EXA  810
      EXTC(M,N)=FG1EXT(N)                                            EXA  820
      GO TO 80                                                       EXA  830
   55 ABSC(M,N)=FG2ABS(N)                                            EXA  840
      EXTC(M,N)=FG2EXT(N)                                            EXA  850
      GO TO 80                                                       EXA  860
   60 ABSC(M,N)=BSTABS(N)                                            EXA  870
      EXTC(M,N)=BSTEXT(N)                                            EXA  880
      GO TO 80                                                       EXA  890
   65 ABSC(M,N)=AVOABS(N)                                            EXA  900
      EXTC(M,N)=AVOEXT(N)                                            EXA  910
      GO TO 80                                                       EXA  920
   70 ABSC(M,N)=FVOABS(N)                                            EXA  930
      EXTC(M,N)=FVOEXT(N)                                            EXA  940
      GO TO 80                                                       EXA  950
   75 ABSC(M,N)=DMEABS(N)                                            EXA  960
      EXTC(M,N)=DMEEXT(N)                                            EXA  970
   80 CONTINUE                                                       EXA  980
   85 CONTINUE                                                       EXA  990
      PRINT 95                                                       EXA 1000
C     PRINT 100, (VX2(N),(EXTC(M,N),ABSC(M,N),M=1,4),N=1,40)         EXA 1010
      RETURN                                                         EXA 1020
C                                                                    EXA 1030
   90 FORMAT (7H   ICH   ,4I5)                                       EXA 1040
   95 FORMAT (40H  EXTINCTION AND ABSORPTION COEFFICIENTS)           EXA 1050
  100 FORMAT (F10.4,8F10.5)                                          EXA 1060
      END                                                            EXA 1070
```

```
      SUBROUTINE EXTDTA
C
C     AEROSOL EXTINCTION AND ABSORPTION DATA
C
      COMMON /EXTDTA/VX2(40),RUREXT(40,4),RURABS(40,4),URBEXT(40,4),
     1URBABS(40,4),OCNEXT(40,4),OCNABS(40,4),TROEXT(40,4),TROABS(40,4),
     2FG1EXT(40),FG1ABS(40),FG2EXT(40),FG2ABS(40)
     3,  BSTEXT(40),BSTABS(40),AVOEXT(40),AVOABS(40),FVOEXT(40
     4),FVOABS(40),DMEEXT(40),DMEABS(40)
      DATA (VX2(I),I=    1,   40)/
     *   .2000,    .3000,    .3371,    .5500,    .6943,   1.0600,   1.5360,
     *  2.0000,   2.2500,   2.5000,   2.7000,   3.0000,   3.3923,   3.7500,
     *  4.5000,   5.0000,   5.5000,   6.0000,   6.2000,   6.5000,   7.2000,
     *  7.9000,   8.2000,   8.7001,   9.0000,   9.2000,  10.0000,  10.5910,
     * 11.0000,  11.5000,  12.5000,  14.8000,  15.0000,  16.4000,  17.2000,
     * 18.5000,  21.3000,  25.0000-  30.0000,  40.0000/
      DATA (RUREXT(I,1) ,I=1, 40)/
     1 2.09291, 1.74582, 1.60500, 1.00000,  .75203,  .41943,  .24070,
     2  .14709,  .13304,  .12234,  .13247,  .11196,  .10437,  .09956,
     3  .09199,  .08449,  .07861,  .07025,  .07089,  .07196,  .07791,
     4  .04481,  .04399,  .12184,  .12658,  .12829,  .09152,  .08076,
     5  .07456,  .06880,  .06032,  .04949,  .05854,  .06000,  .06962,
     6  .05722,  .06051,  .05177,  .04589,  .04304/
      DATA (RUREXT(I,2) ,I=1, 40)/
     1 2.09544, 1.74165, 1.59981, 1.00000,  .75316,  .42171,  .24323,
     2  .15108,  .13608,  .12430,  .13222,  .13823,  .11076,  .10323,
     3  .09475,  .08728,  .08075,  .07639,  .07797,  .07576,  .07943,
     4  .04899,  .04525,  .12165,  .12741,  .12778,  .09032,  .07962,
     5  .07380,  .06880,  .06329,  .05791,  .06646,  .06539,  .07443,
     6  .06304,  .06443,  .05539,  .04867,  .04519/
      DATA (RUREXT(I,3) ,I=1, 40)/
     1 2.07082, 1.71456, 1.57962, 1.00000,  .76095,  .43228,  .25348,
     2  .16456,  .14677,  .13234,  .13405,  .20316,  .12873,  .11506,
     3  .10481,  .09709,  .08919,  .09380,  .09709,  .08791,  .08601,
     4  .06247,  .05601,  .11905,  .12595,  .12348,  .08741,  .07703,
     5  .07266,  .07044,  .07443,  .08146,  .08810,  .08563,  .08962,
     6  .08051,  .07677,  .06658,  .05747,  .05184/
      DATA (RUREXT(I,4) ,I=1, 40)/
     1 1.66076, 1.47886, 1.40139, 1.00000,  .80652,  .50595,  .32259,
     2  .23468,  .20772,  .18532,  .17348,  .35114,  .20006,  .17386,
     3  .16139,  .15424,  .14557,  .16215,  .16766,  .14994,  .14032,
     4  .12968,  .12601,  .13551,  .13582,  .13228,  .11070,  .09994,
     5  .09873,  .10418,  .13241,  .15924,  .16139,  .15949,  .15778,
     6  .15184,  .13848,  .12563,  .11076,  .09601/
      DATA (RURABS(I,1) ,I=1, 40)/
     1  .67196,  .11937,  .08505,  .05930,  .05152,  .05816,  .05006,
     2  .01968,  .02070,  .02101,  .05652,  .02785,  .01316,  .00867,
     3  .01462,  .01310,  .01627,  .02013,  .02165,  .02367,  .03538,
     4  .02823,  .03962,  .06779,  .07285,  .08120,  .04032,  .03177,
     5  .02557,  .02342,  .02177,  .02627,  .03943,  .03114,  .03696,
     6  .02956,  .03500,  .03241,  .03297,  .03380/
      DATA (RURABS(I,2) ,I=1, 40)/
     1  .62968,  .10816,  .07671,  .05380,  .04684,  .05335,  .04614,
     2  .01829,  .01899,  .01962,  .05525,  .06816,  .01652,  .00867,
     3  .01546,  .01373,  .01677,  .02892,  .02829,  .02532,  .03487,
     4  .02835,  .03854,  .06684,  .07272,  .08038,  .03987,  .03247,
     5  .02816,  .02816,  .03101,  .03741,  .04829,  .04032,  .04399,
     6  .03734,  .03956,  .03601,  .03525,  .03563/
      DATA (RURABS(I,3) ,I=1, 40)/
     1  .51899,  .08278,  .05815,  .04082,  .03570,  .04158,  .03620,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     2 .01513, .01481, .01633, .05278, .13690, .02494, .00886,      EXT 610
     3 .01804, .01582, .01677, .04816, .04367, .03013, .03443,      EXT 620
     4 .02930, .03677, .06209, .06911, .07475, .03892, .03494,      EXT 630
     5 .03513, .03968, .05152, .06241, .06937, .06203, .06215,      EXT 640
     6 .05614, .05209, .04608, .04196, .04095/                      EXT 650
      DATA (RURABS(I,4) ,I=1, 40)/                                  EXT 660
     1 .21943, .02848, .01943, .01342, .01171, .01437, .01323,      EXT 670
     2 .01152, .06696, .01329, .06108, .24690, .05323, .01430,      EXT 680
     3 .03361, .02949, .02652, .09437, .08506, .05348, .04627,      EXT 690
     4 .04363, .04557, .05383, .05715, .05899, .04861, .05253,      EXT 700
     5 .06171, .07437, .10152, .12019, .12190, .11734, .11411,      EXT 710
     6 .10766, .09487, .08430, .07348, .06861/                      EXT 720
      DATA (URBEXT(I,1) ,I=1, 40)/                                  EXT 730
     1 1.88815, 1.63316, 1.51867, 1.00000, .77785, .47095, .30006,  EXT 740
     2 .21392, .19405, .17886, .18127, .16133, .14785, .14000,      EXT 750
     3 .12715, .11880, .11234, .10601, .10500, .10361, .10342,      EXT 760
     4 .08766, .08652, .11937, .12139, .12297, .09757, .09057,      EXT 770
     5 .08595, .08196, .07563, .06696, .07209, .06842, .07177,      EXT 780
     6 .05354, .06177, .05373, .04728, .04051/                      EXT 790
      DATA (URBEXT(I,2) ,I=1, 40)/                                  EXT 800
     1 1.95582, 1.64994, 1.53070, 1.00000, .77614, .46639, .29487,  EXT 810
     2 .21051, .18943, .17285, .17209, .21418, .15354, .14051,      EXT 820
     3 .12728, .11861, .11083, .11329, .11323, .10563, .10247,      EXT 830
     4 .08696, .08361, .12013, .12418, .12304, .09614, .08842,      EXT 840
     5 .08487, .08285, .08361, .08430, .08880, .08449, .08601,      EXT 850
     6 .07835, .07323, .06367, .05500, .04747/                      EXT 860
      DATA (URBEXT(I,3) ,I=1, 40)/                                  EXT 870
     1 1.96430, 1.64032, 1.52392, 1.00000, .77709, .46253, .20690,  EXT 880
     2 .20310, .17981, .16101, .15614, .26475, .15456, .13563,      EXT 890
     3 .12215, .11361, .10500, .11715, .11753, .10392, .09766,      EXT 900
     4 .08443, .08057, .10943, .11342, .11063, .08703, .08025,      EXT 910
     5 .07886, .08032, .09101, .10070, .10386, .09943, .09886,      EXT 920
     6 .09152, .08247, .07152, .06089, .05253/                      EXT 930
      DATA (URBEXT(I,4) ,I=1, 40)/                                  EXT 940
     1 1.41266, 1.33816, 1.29114, 1.00000, .83646, .55025, .35342,  EXT 950
     2 .25285, .21576, .18310, .16215, .37854, .20494, .16665,      EXT 960
     3 .14778, .13842, .12943, .15575, .15709, .13513, .12481,      EXT 970
     4 .11759, .11494, .11487, .11329, .11108, .09911, .09209,      EXT 980
     5 .09342, .10120, .13177, .15696, .15766, .15513, .15203,      EXT 990
     6 .14532, .13038, .11785, .10411, .09101/                      EXT 1000
      DATA (URBABS(I,1) ,I=1, 40)/                                  EXT 1010
     1 .78437, .58975, .54285, .36184, .29222, .20886, .15658,      EXT 1020
     2 .12329, .11462, .10747, .11797, .10025, .08759, .08184,      EXT 1030
     3 .07506, .07006, .06741, .06601, .06544, .06449, .06665,      EXT 1040
     4 .06278, .06949, .07316, .07462, .08101, .05753, .05272,      EXT 1050
     5 .04899, .04734, .04494, .04447, .05133, .04348, .04443,      EXT 1060
     6 .03994, .03981, .03633, .03468, .03146/                      EXT 1070
      DATA (URBABS(I,2) ,I=1, 40)/                                  EXT 1080
     1 .69032, .49367, .45165, .29741, .24070, .17399, .13146,      EXT 1090
     2 .10354, .09589, .09025, .10411, .15101, .07880, .06949,      EXT 1100
     3 .06170, .06095, .05829, .07171, .06797, .05975, .06113,      EXT 1110
     4 .05589, .06051, .07139, .07494, .07956, .05525, .05184,      EXT 1120
     5 .05089, .05291, .05885, .06380, .06880, .06127, .06019,      EXT 1130
     6 .05525, .05070, .04500, .04076, .03741/                      EXT 1140
      DATA (URBABS(I,3) ,I=1, 40)/                                  EXT 1150
     1 .54848, .37101, .33734, .21949, .17785, .12968, .09354,      EXT 1160
     2 .07804, .07165, .06791, .08563, .18639, .06722, .05316,      EXT 1170
     3 .05316, .04816, .04620, .07570, .06899, .05291, .05101,      EXT 1180
     4 .04734, .05025, .06171, .06570, .06854, .04892, .04797,      EXT 1190
     5 .05057, .05665 .07127, .08095, .08411, .07728, .07475,       EXT 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
6  .06886,  .06019,  .05222,  .04538,  .04171/                        EXT 1210
 DATA (URBABS(I,4) ,I=1, 40)/                                         EXT 1220
1  .15975,  .10000,  .09013,  .05785,  .04671,  .03424,  .02633,      EXT 1230
2  .02525,  .01975,  .02354,  .06241,  .26690,  .09810,  .02285,      EXT 1240
3  .03810,  .03386,  .03044,  .09627,  .08557,  .05465,  .04576,      EXT 1250
4  .04392,  .04474,  .04671,  .04791,  .04861,  .04654,  .05177,      EXT 1260
5  .06159,  .07475,  .10342,  .12146,  .12177,  .11734,  .11335,      EXT 1270
6  .10608,  .09171,  .08063,  .06968,  .06475/                        EXT 1280
 DATA (OCNEXT(I,1) ,I=1, 40)/                                         EXT 1290
1 1.47576, 1.32614, 1.26171, 1.00000,  .88133,  .70257,  .56487,      EXT 1300
2  .46006,  .42044,  .38310,  .35076,  .42266,  .32278,  .28810,      EXT 1310
3  .24905,  .21184,  .16734,  .14791,  .21532,  .15076,  .12057,      EXT 1320
4  .10038,  .10703,  .15070,  .15665,  .14639,  .10228,  .08367,      EXT 1330
5  .07373,  .06829,  .05044,  .04373,  .04962,  .06158,  .07703,      EXT 1340
6  .07234,  .06297,  .05481,  .05329,  .08741/                        EXT 1350
 DATA (OCNEXT(I,2) ,I=1, 40)/                                         EXT 1360
1 1.36924, 1.25443, 1.20835, 1.00000,  .91367,  .77089,  .64987,      EXT 1370
2  .54886,  .50247,  .45038,  .38209,  .50589,  .43766,  .38076,      EXT 1380
3  .31658,  .27475,  .22215,  .21019,  .27570,  .23057,  .16949,      EXT 1390
4  .14209,  .14215,  .16956,  .17082,  .16025,  .11665,  .09759,      EXT 1400
5  .09215,  .09373,  .10532,  .12570,  .13000,  .13633,  .14291,      EXT 1410
6  .13506,  .11475,  .09658,  .08291,  .10348/                        EXT 1420
 DATA (OCNEXT(I,3) ,I=1, 40)/                                         EXT 1430
1 1.22259, 1.14627, 1.11842, 1.00000,  .94766,  .87538,  .80418,      EXT 1440
2  .72930,  .68592,  .62165,  .49962,  .67949,  .66468,  .59253,      EXT 1450
3  .49551,  .44671,  .37886,  .35924,  .43367,  .37019,  .30842,      EXT 1460
4  .26437,  .25228,  .24905,  .23975,  .22766,  .17804,  .15316,      EXT 1470
5  .15373,  .16791,  .22361,  .28348,  .28677,  .29082,  .29038,      EXT 1480
6  .27810,  .23867,  .20209,  .16430,  .14943/                        EXT 1490
 DATA (OCNEXT(I,4) ,I=1, 40)/                                         EXT 1500
1 1.09133, 1.06601, 1.05620, 1.00000,  .97506,  .94791,  .94203,      EXT 1510
2  .93671,  .92867,  .90411,  .80253,  .89222,  .94462,  .92146,      EXT 1520
3  .85797,  .82595,  .76747,  .68646,  .78209,  .75266,  .68658,      EXT 1530
4  .62722,  .60228,  .56335,  .53728,  .51861,  .47449,  .37196,      EXT 1540
5  .35899,  .37316,  .46854,  .58234,  .58690,  .60348,  .60563,      EXT 1550
6  .60009,  .55392,  .50367,  .43576,  .35949/                        EXT 1560
 DATA (OCNABS(I,1) ,I=1, 40)/                                         EXT 1570
1  .30987,  .04354,  .02880,  .01797,  .01468,  .01766,  .01582,      EXT 1580
2  .00816,  .01146,  .01677,  .03310,  .03380,  .00715,  .00443,      EXT 1590
3  .00500,  .00601,  .00753,  .01595,  .02943,  .00994,  .01367,      EXT 1600
4  .0167 ,  .02578,  .03481,  .03405,  .03601,  .01608,  .01310,      EXT 1610
5  .01152,  .01082,  .01070,  .01563,  .02063,  .03171,  .03810,      EXT 1620
6  .03741,  .03804,  .03763,  .04209,  .07892/                        EXT 1630
 DATA (OCNABS(I,2) ,I=1, 40)/                                         EXT 1640
1  .23367,  .03127,  .02070,  .01297,  .01063,  .01285,  .01190,      EXT 1650
2  .00937,  .00911,  .01575,  .05576,  .23487,  .03949,  .00905,      EXT 1660
3  .02057,  .01816,  .01665,  .06025,  .08044,  .03677,  .03139,      EXT 1670
4  .03190,  .03766,  .04532,  .04544,  .04715,  .03405,  .03614,      EXT 1680
5  .04329,  .05424,  .07823,  .09728,  .10057,  .10247,  .10222,      EXT 1690
6  .09551,  .08241,  .07158,  .06506,  .09203/                        EXT 1700
 DATA (OCNABS(I,3) ,I=1, 40)/                                         EXT 1710
1  .13025,  .01557,  .01013,  .00646,  .00532,  .00665,  .00722,      EXT 1720
2  .01335,  .00728,  .01810,  .09835,  .37329,  .09703,  .01968,      EXT 1730
3  .05114,  .04342,  .03709,  .17456,  .16468,  .08785,  .06800,      EXT 1740
4  .06589,  .06791,  .07247,  .07329,  .07449,  .07025,  .07962,      EXT 1750
5  .09899,  .12481,  .17867,  .22019,  .22228,  .22051,  .21595,      EXT 1760
6  .20335,  .17278,  .14677,  .12171,  .12430/                        EXT 1770
 DATA (OCNABS(I,4) ,I=1, 40)/                                         EXT 1780
1  .03506,  .00323,  .00215,  .00139,  .00114,  .00171,  .00532,      EXT 1790
2  .03082,  .01101,  .03741,  .20101,  .47608,  .21165,  .05234,      EXT 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
3  .12886,  .11215,  .09684,  .32810,  .31778,  .20513,  .16658,    EXT 1810
4  .15956,  .15842,  .15905,  .15968,  .16051,  .16506,  .18323,    EXT 1820
5  .21709,  .25652,  .33222,  .39639,  .39854,  .40297,  .40025,    EXT 1830
6  .39025,  .35468,  .32006,  .27715,  .25348/                      EXT 1840
 DATA (TROEXT(I,1) ,I=1, 40)/                                       EXT 1850
1 2.21222, 1.82753, 1.67032, 1.00000, .72424,  .35272,  .15234,    EXT 1860
2  .05165,  .03861,  .02994,  .04671,  .02462,  .01538,  .01146,    EXT 1870
3  .01032,  .00816,  .00861,  .00994,  .01057,  .01139,  .01747,    EXT 1880
4  .01494,  .02418,  .03165,  .03386,  .04247,  .01601,  .01215,    EXT 1890
5  .00977,  .00861,  .00823,  .01139,  .01924,  .01234,  .01348,    EXT 1900
6  .01114,  .01297,  .01266,  .01418,  .01487/                      EXT 1910
 DATA (TROEXT(I,2) ,I=1, 40)/                                       EXT 1920
1 2.21519, 1.82266, 1.66557, 1.00000, .72525,  .35481,  .15449,    EXT 1930
2  .05475,  .04044,  .03082,  .04620,  .05272,  .01867,  .01266,    EXT 1940
3  .01127,  .00886,  .00885,  .01449,  .01399,  .01228,  .01728,    EXT 1950
4  .01475,  .02285,  .03215,  .03494,  .04285,  .01652,  .01304,    EXT 1960
5  .01101,  .01120,  .01297,  .01753,  .02468,  .01741,  .01766,    EXT 1970
6  .01513,  .01557,  .01456,  .01532,  .01582/                      EXT 1980
 DATA (TROEXT(I,3) ,I=1, 40)/                                       EXT 1990
1 2.19082, 1.79462, 1.64456, 1.00000, .73297,  .36443,  .16278,    EXT 2000
2  .06468,  .04658,  .03799,  .04538,  .11892,  .02835,  .01646,    EXT 2010
3  .01386,  .01076,  .00968,  .02551,  .02222,  .01468,  .01690,    EXT 2020
4  .01437,  .01994,  .03127,  .03513,  .04076,  .01722,  .01513,    EXT 2030
5  .01519,  .01791,  .02538,  .03272,  .03816,  .03038,  .02886,    EXT 2040
6  .02551,  .02228,  .01937,  .01804,  .01791/                      EXT 2050
 DATA (TROEXT(I,4) ,I=1, 40)/                                       EXT 2060
1 1.75696, 1.54829, 1.45962, 1.00000, .77816,  .43139,  .21778,    EXT 2070
2  .11329,  .08101,  .05506,  .04943,  .25291,  .06816,  .03703,    EXT 2080
3  .02601,  .01968,  .01468,  .04962,  .04247,  .02234,  .01797,    EXT 2090
4  .01532,  .01633,  .02259,  .02487,  .02595,  .01728,  .01892,    EXT 2100
5  .02399,  .03247,  .05285,  .06462,  .06608,  .05930,  .05525,    EXT 2110
6  .04861,  .03753,  .02968,  .02348,  .02165/                      EXT 2120
 DATA (TROABS(I,1) ,I=1, 40)/                                       EXT 2130
1  .69671,  .09906,  .06563,  .04101,  .03354,  .03627,  .02810,    EXT 2140
2  .00873,  .00918,  .00930,  .03215,  .01285,  .00513,  .00316,    EXT 2150
3  .00557,  .00494,  .00646,  .00867,  .00937,  .01025,  .01646,    EXT 2160
4  .01481,  .02418,  .02885,  .03070,  .04032,  .01494,  . 1139,    EXT 2170
5  .00873,  .00816,  .00797,  .01133,  .01911,  .01215,  .01329,    EXT 2180
6  .01101,  .01291,  .01266,  .01418,  .01487/                      EXT 2190
 DATA (TROABS(I,2) ,I=1, 40)/                                       EXT 2200
1  .65000,  .08791,  .05816,  .03652,  .02994,  .03278,  .02557,    EXT 2210
2  .00810,  .00842,  .00867,  .03139,  .03949,  .00646,  .00316,    EXT 2220
3  .00595,  .00519,  .00646,  .01304,  .01247,  .01095,  .01620,    EXT 2230
4  .01449,  .02278,  .02930,  .03184,  .04063,  .01544,  .01234,    EXT 2240
5  .01044,  .01076,  .01272,  .01741,  .02462,  .01722,  .01747,    EXT 2250
6  .01506,  .01551,  .01456,  .01532,  .01582/                      EXT 2260
 DATA (TROABS(I,3) ,I=1, 40)/                                       EXT 2270
1  .52804,  .06367,  .04159,  .02633,  .02184,  .02443,  .01937,    EXT 2280
2  .00658,  .00646,  .00709,  .02949,  .10013,  .00968,  .00310,    EXT 2290
3  .00677,  .00582,  .00646,  .02361,  .01994,  .01266,  .01544,    EXT 2300
4  .01386,  .01968,  .02648,  .03203,  .03854,  .01620,  .01449,    EXT 2310
5  .01462,  .01747,  .02513,  .03253,  .03797,  .03019,  .02861,    EXT 2320
6  .02538,  .02215,  .01930,  .01797,  .01791/                      EXT 2330
 DATA (TROABS(I,4) ,I=1, 40)/                                       EXT 2340
1  .19829,  .01842,  .01215,  .00791,  .00665,  .00778,  .00652,    EXT 2350
2  .00361,  .00253,  .00393,  .02570,  .20690,  .01715,  .00316,    EXT 2360
3  .00873,  .00728,  .00658,  .04481,  .03525,  .01646,  .01405,    EXT 2370
4  .01310,  .01468,  .01955,  .02184,  .02367,  .01608,  .01816,    EXT 2380
5  .02342,  .03203,  .05234,  .06399.  .06538,  .05867,  .05456,    EXT 2390
6  .04810,  .03715,  .02949,  .02335,  .02158/                      EXT 2400
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      DATA(FG1EXT(I),I=1, 40)/
     1  .98519,  .99158,  .99089, 1.00000, 1.00576, 1.01747, 1.03177,
     2 1.04146, 1.04696, 1.05323, 1.05886, 1.04899, 1.06823, 1.07804,
     3 1.09272, 1.10367, 1.11684, 1.10430, 1.11367, 1.12899, 1.14987,
     4 1.17209, 1.18278, 1.20133, 1.21266, 1.21949, 1.22677, 1.16589,
     5 1.05684,  .98291, 1.01120, 1.10911, 1.11462, 1.14671, 1.16247,
     6 1.18544, 1.21582, 1.24614, 1.26842, 1.20500/
      DATA(FG1ABS(I),I=1, 40)/
     1  .00013, 0.00000, 0.00000, 0.00000, 0.00000,  .00095,  .01513,
     2  .10861,  .03892,  .13272,  .47133,  .49696,  .45785,  .17918,
     3  .37373,  .34601,  .31867,  .55190,  .55025,  .49987,  .46342,
     4  .45943,  .45918,  .46083,  .46241,  .46386,  .47196,  .48905,
     5  .51468,  .57101,  .55266,  .58665,  .58899,  .60367,  .61158,
     6  .62335,  .64120,  .65627,  .66278,  .66392/
      DATA(FG2EXT(I),I=1, 40)/
     1  .94791,  .96215,  .97063, 1.00000, 1.00937, 1.05177, 1.12519,
     2 1.29570, 1.39203, 1.41120, 1.04715, 1.10816, 1.43285, 1.45272,
     3 1.18709, 1.04367,  .82354,  .71747,  .92405,  .79342,  .60266,
     4  .47677,  .43171,  .36734,  .33259,  .31184,  .24139,  .21601,
     5  .24006,  .28816,  .42671,  .56861,  .57266,  .58089,  .57165,
     6  .54247,  .47981,  .34475,  .24905,  .19291/
      DATA(FG2ABS(I),I=1, 40)/
     1 0.00000, 0.00000, 0.00000, 0.00000, 0.00000,  .00013,  .00247,
     2  .01987,  .00620,  .02323,  .17209,  .57930,  .19810,  .03475,
     3  .09639,  .08000,  .06582,  .34589,  .32703,  .17025,  .12633,
     4  .11316,  .11627,  .11513,  .11538,  .11601,  .12329,  .14468,
     5  .18633,  .24057,  .35411,  .44886,  .45095,  .45215,  .44278,
     6  .41778,  .34432,  .27823,  .21063,  .17857/
      DATA(BSTEXT(I),I=1, 40)/
     1 1.48671, 1.55462, 1.51506, 1.00000,  .70633,  .28867,  .09994,
     2  .04184,  .02728,  .01848,  .01335,  .05513,  .08930,  .06532,
     3  .04766,  .04278,  .05811,  .05367,  .04392,  .03342,  .04456,
     4  .11867,  .14799,  .17734,  .09291,  .08778,  .05013,  .04070,
     5  .05734,  .03576,  .01975,  .01892,  .01956,  .03665,  .04152,
     6  .01715,  .01620,  .00835,  .00633,  .00589/
      DATA(BSTABS(I),I=1, 40)/
     1 0.00000, 0.00000, 0.00000, 0.00000, 0.00000, 0.00000,  .00019,
     2  .00127,  .00158,  .00291,  .00405,  .05880,  .08297,  .06019,
     3  .04519,  .04133,  .05703,  .05266,  .04304,  .03265,  .04437,
     4  .11816,  .14633,  .12639,  .09215,  .08722,  .04968,  .04044,
     5  .05709,  .03551,  .01952,  .01892,  .01949,  .03655,  .04146,
     6  .01709,  .01620,  .00835,  .00633,  .00589/
      DATA(AVOEXT(I),I=1, 40)/
     1 1.14880, 1.19171, 1.18013, 1.00000,  .84873,  .57019,  .27968,
     2  .14551,  .11070,  .08633,  .07184,  .06076,  .04506,  .03399,
     3  .02095,  .01538,  .01266,  .01019,  .00994,  .01044,  .01361,
     4  .01791,  .02278,  .02918,  .03108,  .03234,  .03456,  .03184,
     5  .02772,  .02475,  .01715,  .01563,  .01665,  .01646,  .01734,
     6  .01772,  .01076,  .01051,  .01137,  .01329/
      DATA(AVOABS(I),I=1, 40)/
     1  .44816,  .11259,  .08500,  .05272,  .04082,  .02449,  .01487,
     2  .01019,  .00867,  .00842,  .00842,  .00949,  .00741,  .00487,
     3  .00316,  .00335,  .00333,  .00449,  .00525,  .00665,  .01114,
     4  .01652,  .02177,  .02437,  .02506,  .02658,  .03006,  .02861,
     5  .02513,  .02285,  .01620,  .01532,  .01633,  .01620,  .01709,
     6  .01741,  .01057,  .01038,  .01127,  .01329/
      DATA(FVOEXT(I),I=1, 40)/
     1  .68715,  .92532,  .94013, 1.00000, 1.03013, 1.05575, 1.01171,
     2  .88677,  .82538,  .76361,  .71563,  .67424,  .60589,  .55057,
     3  .45222,  .37646,  .32316,  .25519,  .22728,  .20525,  .17810,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     4 .14481,  .14152,  .37633,  .44551,  .44405,  .42222,  .36462,   EXT 3010
     5 .32551,  .27519,  .16728,  .10627,  .10861,  .10885,  .11665,   EXT 3020
     6 .13127,  .10108,  .08557,  .06411,  .05741/                     EXT 3030
      DATA(FVOABS(I),I=1, 40)/                                         EXT 3040
     1 .41582,  .22892,  .19108,  .14468,  .12475,  .09158,  .06601,   EXT 3050
     2 .04943,  .04367,  .04342,  .04399,  .05076,  .04133,  .02829,   EXT 3060
     3 .01924,  .01981,  .02297,  .02475,  .02778,  .03411,  .05335,   EXT 3070
     4 -.07133, .08816,  .15342,  .18506,  .19354,  .20791,  .18449,   EXT 3080
     5 .16101,  .13759,  .08455,  .06886,  .07278,  .07367,  .07956,   EXT 3090
     6 .08785,  .06032,  .05747,  .05133,  .05323/                     EXT 3100
      DATA(DMEEXT(I),I=1, 40)/                                         EXT 3110
     1 1.05019, 1.05880, 1.05259, 1.00000, .94949,  .81456,  .66051,   EXT 3120
     2 .54380,  .49133,  .44677,  .41671,  .38063,  .34778,  .32804,   EXT 3130
     3 .29722,  .27506,  .25082,  .22620,  .21652,  .20253,  .17266,   EXT 3140
     4 .14905,  .14234,  .14082,  .15057,  .16399,  .23608,  .24481,   EXT 3150
     5 .27791,  .29076,  .15272,  .09601,  .09456,  .14576,  .12373,   EXT 3160
     6 .18348,  .12150,  .12924,  .08538,  .04108/                     EXT 3170
      DATA(DMEABS(I),I=1, 40)/                                         EXT 3180
     1 .00063,  .00152,  .00184,  .00506,  .00791,  .01829,  .03728,   EXT 3190
     2 .06158,  .07538,  .08943,  .10051,  .11614,  .13310,  .14348,   EXT 3200
     3 .14633,  .13728,  .12462,  .11184,  .10709,  .10076,  .09006,   EXT 3210
     4 .08734,  .09000,  .10304,  .11905,  .13437,  .19551,  .20095,   EXT 3220
     5 .22494,  .18418,  .09235,  .06665,  .06823,  .12329,  .10551,   EXT 3230
     6 .16184,  .09835,  .10582,  .06759,  .03247/                     EXT 3240
      RETURN                                                           EXT 3250
CCC                                                                    EXT 3260
CCC   ALTITUDE REGIONS FOR AEROSOL EXTINCTION COEFFICIENTS             EXT 3270
CCC                                                                    EXT 3280
CCC                                                                    EXT 3290
CCC         0-2KM                                                      EXT 3300
CCC           RUREXT=RURAL EXTINCTION    RURABS=RURAL ABSORPTION       EXT 3310
CCC           URBEXT=URBAN EXTINCTION    URBABS=URBAN ABSORPTION       EXT 3320
CCC           OCNEXT=MARITIME EXTINCTION  OCNABS=MARITIME ABSORPTION   EXT 3330
CCC           TROEXT=TROPSPHER EXTINCTION  TROABS=TROPOSPHER ABSORPTION EXT 3340
CCC           FG1EXT=FOG1 .2KM VIS EXTINCTION  FG1ABS=FOG1 ABSORPTION  EXT 3350
CCC           FG2EXT=FOG2 .5KM VIS EXTINCTION  FG2ABS=FOG2 ABSORPTION  EXT 3360
CCC         >2-9KM                                                     EXT 3370
CCC           TROEXT=TROPOSPHER EXTINCTION  TROABS=TROPOSPHER ABSORPTIONEXT 3380
CCC         >9-30KM                                                    EXT 3390
CCC           BSTEXT=BACKGROUND STRATOSPHERIC EXTINCTION               EXT 3400
CCC           BSTABS=BACKGROUND STRATOSPHERIC ABSORPTION               EXT 3410
CCC           AVOEXT=AGED VOLCANIC EXTINCTION                          EXT 3420
CCC           AVOABS=AGED VOLCANIC ABSORPTION                          EXT 3430
CCC           FVOEXT=FRESH VOLCANIC EXTINCTION                         EXT 3440
CCC           FVOABS=FRESH VOLCANIC ABSORPTION                         EXT 3450
CCC         >30-100KM                                                  EXT 3460
CCC           DMEEXT=METEORIC DUST EXTINCTION                          EXT 3470
CCC           DMEABS=METEORIC DUST ABSORPTION                          EXT 3480
      END                                                              EXT 3490
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE PATH
C                                                    REVISED 12 DEC 79
C     LOADS CUMULATIVE ABSORBER AMOUNTS INTO THE MATRIX WPATH FROM WLAY
C        FOR THE ATMOSPHERIC SLANT PATH
C     USED FOR RADIANCE CALCULATIONS
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,FI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      IF (ITYPE.EQ.1) GO TO 60
      IF (J1.EQ.J2.AND.J1.EQ.JMIN) GO TO 60
      IF (ITYPE.EQ.2.AND.H1.EQ.H2) J2=J1
      IF (H2.GT.H1.AND.ANGLE.GT.90..AND.NP1.EQ.1) J1=J1-1
      IF (JEXTRA.EQ.1) J2=J2+1
      IF ((ITYPE.EQ.2).AND.(H1.GT.H2).AND.(LENST.EQ.1)) J2=J2-1
      IF (ITYPE.EQ.3) J2=NL
      IF (JP.EQ.0) PRINT 70, J1,J2
      IF(JP.EQ.0) PRINT 75
      DO 5 IK=1,68
      TBBY(IK)=0.
      DO 5 K=1,KMAX
      WPATH(IK,K)=0.
    5 CONTINUE
      LEN=0
      NLL=NL-1
      IL=J1+1
      IJ=IL+NLL
      DO 10 K=1,KMAX
      E(K)=0.
   10 CONTINUE
      IF (ANGLE.GT.90.0) GO TO 15
      LEN=1.
      IL=J1-1
      HMIN=1.0E-6
      IJ=NLL
   15 CONTINUE
      DO 40 IK=1,68
      IF (LEN.EQ.0) IL=IL-1
      IF (LEN.EQ.1) IL=IL+1
      IJ=IJ-1
      IF (IL.EQ.0) GO TO 40
      DO 20 K=1,KMAX
      W(K)=E(K)+WLAY(IL,K)
      WPATH(IK,K)=W(K)
   20 CONTINUE
      IF (IL.LE.0.OR.IL.GE.NL) GO TO 25
      TBAR=(T(M,IL)+T(M,IL+1))*0.5
      IF(M1.GT.0.AND.M.LT.7) TBAR=(T(M1,IL)+T(M1,IL+1))*0.5
C
C     IF (JEXTRA.EQ.1) TBAR=(T(M,J1)+T(M,J1+1))*0.5
   25 CONTINUE
      TBBY(IK)=TBAR
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      DO 30 K=1,KMAX
      E(K)=W(K)
   30 CONTINUE
      IF (ANGLE.LE.90.0.AND.IL.EQ.NLL) GO TO 50
      IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 35
      IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 50
      IF (ITYPE.EQ.2.AND.LENST.EQ.0.AND.IL.EQ.J2) GO TO 50
      IF (IL.EQ.JMIN.AND.HMIN.GT.0.0) LEN=1
      IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 50
      IF (LEN.EQ.0) GO TO 35
      IF (IL.EQ.JMIN.AND.IJ.EQ.IL+NLL) IL=IL-1
      IF (ITYPE.EQ.2.AND.IL.EQ.J2) GO TO 50
   35 CONTINUE
      IF(JP.EQ.0)PRINT 80, IK,(WPATH(IK,K),K=1,8), WPATH(IK,10),
     1WPATH(IK,11),TBBY(IK)
   40 CONTINUE
      IKMAX=68
      LEN=LENST
      IF(JP.NE.0) RETURN
      PRINT 85
      DO 45 IK=1,IKMAX
   45 PRINT 80, IK,(WPATH(IK,K),K=12,14)
      RETURN
   50 CONTINUE
      IF(JP.EQ.0) PRINT 80, IK,(WPATH(IK,K),K=1,8),WPATH(IK,10)
     1 ,WPATH(IK,11),TBBY(IK)
      IKMAX=IK
      LEN=LENST
      IF(JP.NE.0) RETURN
      PRINT 85
      DO 55 IK=1,IKMAX
   55 PRINT 80, IK,(WPATH(IK,K),K=12,14)
      RETURN
   60 DO 65 K=1,KMAX
      WPATH(1,K)=W(K)
   65 CONTINUE
      IF (M.EQ.0) J1=1
      J2=J1
      TBBY(1)=T(M,J1)
      IF(M1.GT.0.AND.M.LT.7) TBBY(1)=T(M1,J1)
      IKMAX=1
      IF(JP.EQ.0) PRINT 70, J1,J2
      IF(JP.EQ.0) PRINT 75
      IK=1
      IKMAX=IK
      IF(JP.EQ.0) PRINT 80, IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),
     1 WPATH(IK,11),TBBY(IK)
      HMIN=1.0E-6
      IF(JP.NE.0) RETURN
      PRINT 85
      PRINT 80, IK,(WPATH(IK,K),K=12,14)
      RETURN
C
   70 FORMAT (9I3)
   75 FORMAT (//,20X,53H CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC
     1 PATH,//10X,3HH2O,6X,4HCO2+,8X,2HO3,9X,2HN2,8X,5HH2O C,6X,5HMOL S,
     27X,4HAER1,6X,5HO3 UV,7X,5HH2O C,7X,4HHNO3,5X,4HTAVE)
   80 FORMAT (I5,1P10E11.3,0PF10.3)
   85 FORMAT (//,2X,2HIK,4X,4HAER2,7X,4HAER3,7X,4HAER4)
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE TRANS
C                                                  REVISED 16 JAN 1980
C     CALCULATES TRANSMITTANCE AND RADIANCE VALUES BETWEEN V1 AND V2
C        FOR A GIVEN ATMOSPHERIC SLANT PATH
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,H(15),C(15),CA,FI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RFLHLM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      COMMON /TRFWFO/ TR(67),FW(67),FO(67)
      COMMON /C4C5C8/ C4(133),C5(15),C8(102)
      COMMON /AER/ XX1,XX2,XX3,XX4,YY1,YY2,YY3,YY4
      DIMENSION ABS(15)
      FF(T,V)=1.190956E-16*(V**5)/(EXP(1.43879*V/T)-1.)
C        WATTS. CM-2 ST-1 MICRON-1
      RADMIN=1.0E+300
      RADMAX=0.
      VRMIN=0.
      VRMAX=0.
      SUMA=0.
      RADSUM=0.
      FACTOR=0.5
      CALL C4DTA
      CALL TRFN
      IV1=V1/5.
      IV2=V2/5.+.99
      IV1=IV1*5
      IV2=IV2*5
      IF (IV1.LT.350) IV1=350
      IF (IV2.GT.50000) IV2=50000
      IF (DV.LT.5) DV=5
      IDV=DV
      IV=IV1-IDV
      ICOUNT=0
C        BEGINING OF TRANSMITTANCE CALCULATIONS
    5 IV=IV+IDV
      SUMV=0.
      TLOLD=1.
      TSOLD=1.
      IKLO=1
      IF (IEMISS.EQ.0) IKMAX=IKLO
      DO 10 JK=1,11
      ABS(JK)=0.
      IF (JK.LE.3) ABS(JK)=-5.
   10 CONTINUE
      IF (JP.NE.0) GO TO 20
      IF (ICOUNT.EQ.0) GO TO 15
      IF (ICOUNT.EQ.50) GO TO 15
      GO TO 20
   15 ICOUNT=0
      IF (IEMISS.EQ.0) PRINT 255
   20 DO 25 K=1,KMAX
      TX(K)=0.0
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (K.LT.4) TX(K)=1.0
   25 CONTINUE
      ICOUNT=ICOUNT+1
      SUM=0.0
      V=IV
      I=(IV-350)/5+1
C     ******************  HNO3
C     HNO3 ABSORPTION CALCULATION
      CALL HNO3 (V,ABS(11))
      IF (IV.LT.670) GO TO 80
      IF (IV.LE.3000) GO TO 45
C     ***   MOLECULAR SCATTERING
      ABS(6)=V**4/(9.26799E+18-1.07123E+09*V**2)
      IF (IV.LT.9200) GO TO 80
      IF (IV.LT.13000) GO TO 65
C     ***  UV OZONE
      IF (IV.LE.23400) GO TO 30
      IF (IV.GE.27500) GO TO 35
      GO TO 110
   30 XI=(V-13000.0)/200.0+1.
      GO TO 40
   35 XI=(V-27500.0)/500.+57.
   40 N=XI+1.001
      XD=XI-FLOAT(N)
      ABS(8)=C8(N)+XD*(C8(N)-C8(N-1))
      IF (IV.GT.14500) GO TO 110
      GO TO 65
C     ***  WATER VAPOR CONTINUUM 10 MICRON REGION
   45 IF (IV.GT.1350) GO TO 50
      ABS(5)=(4.18+5578.0*EXP(-7.87E-3*V))
      GO TO 55
   50 IF (IV.LT.2350) GO TO 60
C     ***  WATER VAPOR CONTINUUM 4 MICRON REGION
      XI=(V-2350.0)/50.0+1.0
      NH=XI+1.001
      XH=XI-FLOAT(NH)
      ABS(10)=C5(NH)+XH*(C5(NH)-C5(NH-1))
   55 CONTINUE
      IF (IV.LE.1350.OR.IV.GT.2740) GO TO 80
C     ***   NITROGEN CONTINUUM
   60 IF (IV.LT.2080) GO TO 80
      K4=I-346
      ABS(4)=C4(K4)
      GO TO 80
C     ***  WATER VAPOUR
   65 IF (IV.LT.12800.AND.IV.GE.9875) GO TO 70
      IF (IV.LE.14520.AND.IV.GE.13400) GO TO 75
      GO TO 85
   70 I=I-135
      GO TO 80
   75 I=I-255
   80 CALL C1DTA (ABS(1),T)
   85 CONTINUE
C     ***   UNIFORMLY MIXED GASES
      IF (IV.LT.8060.AND.IV.GE.500) GO TO 90
      IF (IV.LT.13190.AND.IV.GT.12970) GO TO 95
      GO TO 105
   90 J=I-30
      GO TO 100
   95 J=(IV-12950)/5+1516
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
100 CALL C2DTA (ABS(2),J)
105 CONTINUE
    ***  OZONE
    IF (IV.LT.575.OR.IV.GT.3270) GO TO 110
    L=I-45
    CALL C3DTA (ABS(3),L)
110 CONTINUE
    CALL AEREXT (V)
    DO 210 IK=IKLO,IKMAX
    IF (IEMISS.EQ.0) GO TO 120
    DO 115 K=1,KMAX
    W(K)=WPATH(IK,K)
115 CONTINUE
120 CONTINUE
    SUM=0.
    DO 125 JK=4,11
    TX(JK)=ABS(JK)*W(JK)
125 SUM=SUM+TX(JK)
    TX(5)=TX(5)+TX(10)
    TX(1)=1.0
    K1=1
    IF (W(1).LT.1.0E-20) GO TO 145
    IF (ABS(1).LE.-5.0) GO TO 145
    WS1=ALOG10(W(1))+ABS(1)
    IF (WS1.LT.-2.3468) TX(1)=1.-.087787*EXP(1.855595*WS1)
    IF (WS1.LT.-2.3468) GO TO 145
    IF (WS1.GT.3.5682) GO TO 140
    IF (WS1.GT.2.0) K1=40
    DO 130 K=K1,67
    IF (WS1.LE.FW(K)) GO TO 135
130 CONTINUE
135 TX(1)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS1)/(FW(K)-FW(K-1))
    GO TO 145
140 TX(1)=0.0
145 CONTINUE
    TX(2)=1.0
    K1=1
    IF (W(2).LT.1.0E-20) GO TO 165
    IF (ABS(2).LE.-5.0) GO TO 165
    WS2=ALOG10(W(2))+ABS(2)
    IF (WS2.LT.-2.3468) TX(2)=1.-.087787*EXP(1.855595*WS2)
    IF (WS2.LT.-2.3468) GO TO 165
    IF (WS2.GT.3.5682) GO TO 160
    IF (WS2.GT.2.0) K1=40
    DO 150 K=K1,67
    IF (WS2.LE.FW(K)) GO TO 155
150 CONTINUE
155 TX(2)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS2)/(FW(K)-FW(K-1))
    GO TO 165
160 TX(2)=0.0
165 CONTINUE
    TX(3)=1.
    K1=1
    IF (W(3).LT.1.0E-20) GO TO 185
    IF (ABS(3).LE.-5.0) GO TO 185
    WS3=ALOG10(W(3))+ABS(3)
    IF (WS3.LT.-1.6778) TX(3)=1.-.055194*EXP(2.367853*WS3)
    IF (WS3.LT.-1.6778) GO TO 185
    IF (WS3.GT.3.9345) GO TO 180
    IF (WS3.GT.1.5) K1=36
```

```
      DO 170 K=K1,67
      IF (HS3.LE.FO(K)) GO TO 175
  170 CONTINUE
  175 TX(3)=TR(K)-(TR(K)-TR(K-1))*(FO(K)-HS3)/(FO(K)-FO(K-1))
      GO TO 185
  180 TX(3)=0.0
  185 CONTINUE
      TX(10)=YY1*H(7)+YY2*H(12)+YY3*H(13)+YY4*H(14)
      TX(7)=XX1*H(7)+XX2*H(12)+XX3*H(13)+XX4*H(14)
      SUM=SUM+TX(7)
      TX(9)=SUM
      DO 205 K=4,KMAX
      IF (TX(K).EQ.0.0) GO TO 195
      IF (TX(K).LE.0.1) GO TO 190
      IF (TX(K).GT.20.) GO TO 200
      TX(K)=EXP(-TX(K))
      GO TO 205
  190 TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)
      GO TO 205
  195 TX(K)=1.0
      GO TO 205
  200 TX(K)=0.
  205 CONTINUE
      TX(9)=TX(1)*TX(2)*TX(3)*TX(9)
      IF (IV.GE.13000) TX(3)=TX(8)
      ALAM=1.0E+04/V
      IF (IEMISS.EQ.0) GO TO 220
      BBIK=FF(TBAY(IK),V)
      TLNEW=(TX(9)*TX(10))/(TX(7)*TX(6))
      TSNEW=(TX(7)*TX(6))/TX(10)
      DTAU=TLOLD-TLNEW
      IF (DTAU.LT.1.0E-5.AND.TLNEW.LT.1.0E-5) GO TO 215
      SUMV=SUMV+0.5*BBIK*DTAU*(TSOLD+TSNEW)
      TLOLD=TLNEW
      TSOLD=TSNEW
  210 CONTINUE
  215 CONTINUE
      TAUG=0
      IF (HMIN.LE.0.0.AND.IL.EQ.1) TAUG=TX(9)
      T1=TBOUND
      BBG=FF(T1,V)*TAUG
      IF (HMIN.LE.0.0) SUMV=SUMV+BBG
      SUMVV=SUMV
      IF (IV.GT.IV1) FACTOR=1.0
      IF (IV.GE.IV2) FACTOR=0.5
      SUMV=(1.0E+04/V**2)*SUMV
      RADSUM=RADSUM+DV*FACTOR*SUMV
      IF (JP.EQ.0) PRINT 265, V,ALAM,SUMV,SUMVV,RADSUM,TX(9)
      IF (SUMV.GE.RADMAX) VRMAX=V
      IF (SUMV.GE.RADMAX) RADMAX=SUMV
      IF (SUMV.LE.RADMIN) VRMIN=V
      IF (SUMV.LE.RADMIN) RADMIN=SUMV
      WRITE (7,235) V,ALAM,SUMV,SUMVV,RADSUM,TX(9)
  220 TX(10)=1.-TX(10)
      AB=1.-TX(9)
      IF (IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB
      SUMA=SUMA+AB*DV
      IF (IEMISS.EQ.1) GO TO 225
      IF (JP.EQ.0) WRITE (6,260) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),SUM
     1,TX(11)
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
C     IF(JP.EQ.0)WRITE (6,4R3) IV,ALAM,EXTINC,ABSORB
      WRITE (7,240) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),TX(11)
  225 CONTINUE
      IF (IV.GE.IV2) GO TO 230
      GO TO 5
  230 AB=1.0-SUMA/FLOAT(IV-IV1)
      PRINT 245, IV1,IV,SUMA,AB
      IF (IEMISS.EQ.1) PRINT 250, RADSUM,VRMIN,RADMIN,VRMAX,RADMAX
      RETURN
C
  235 FORMAT (F8.1,F13.5,3E13.5,F13.6)
  240 FORMAT(I6,11F9.4,5X,F9.4)
  245 FORMAT (27H INTEGRATED ABSORPTION FROM,I5,3H TO,I5,7H CM-1 =,F10.2
     1,23HAVERAGE TRANSMITTANCE =,F6.4)
  250 FORMAT (22H INTEGRATED RADIANCE =,E12.5,13HWATT CM -2 SR,/7H RADMI
     1N,F12.3,E12.5,/,8H RADMAX ,F12.3,E12.5)
  255 FORMAT (1H1,/10X,32H  FREQ WAVELENGTH  TOTAL     H2O,5X,4HCO2+,5X,
     164HOZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATE
     2D,12H NITRIC ACID/11X,14H CM-1  MICRONS,8(4X,5HTRANS),4X,20H ABS
     3   ABSORPTION ,4X,5HTRANS)
  260 FORMAT (10X,I6,10F9.4,F14.4,F9.4)
  265 FORMAT (30X,F8.1,F13.5,3E13.5,F13.6)
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE TRFN
C     LOWTRAN TRANSMITTANCE FUNCTIONS
      COMMON /TRFWFO/ TR(67),FH(67),FO(67)
      DATA(TR(I),I=1, 67)/
     1 .9990,  .9980,  .9960,  .9940,  .9920,  .9900,  .9800,  .9700,
     2 .9600,  .9500,  .9400,  .9300,  .9200,  .9100,  .9000,  .8800,
     3 .8600,  .8400,  .8200,  .8000,  .7800,  .7600,  .7400,  .7200,
     4 .7000,  .6800,  .6600,  .6400,  .6200,  .6000,  .5800,  .5600,
     5 .5400,  .5200,  .5000,  .4800,  .4600,  .4400,  .4200,  .4000,
     6 .3800,  .3600,  .3400,  .3200,  .3000,  .2800,  .2600,  .2400,
     7 .2200,  .2000,  .1800,  .1600,  .1400,  .1200,  .1000,  .0800,
     8 .0600,  .0400,  .0300,  .0200,  .0150,  .0100,  .0080,  .0060,
     9 .0040,  .0020,  .0010/
      DATA(FH(I),I=1, 67)/
     1-2.3468,-2.0362,-1.6990,-1.4815,-1.3279,-1.2007, -.7825, -.5229,
     2 -.3468, -.1938, -.0655,  .0414,  .1553,  .2430,  .3324,  .4838,
     3  .6128,  .7243,  .8261,  .9191, 1.0000, 1.0792, 1.1461, 1.2122,
     4 1.2672, 1.3284, 1.3892, 1.4409, 1.4955, 1.5441, 1.5966, 1.6435,
     5 1.6857, 1.7340, 1.7782, 1.8261, 1.8692, 1.9191, 1.9638, 2.0086,
     6 2.0607, 2.1038, 2.1461, 2.1875, 2.2304, 2.2788, 2.3263, 2.3717,
     7 2.4183, 2.4698, 2.5159, 2.5740, 2.6284, 2.6902, 2.7559, 2.8261,
     8 2.9031, 3.0000, 3.0607, 3.1461, 3.2041, 3.2718, 3.3054, 3.3444,
     9 3.3979, 3.4914, 3.5682/
      DATA(FO(I),I=1, 67)/
     1-1.6778,-1.3980,-1.1192, -.9508, -.8239, -.7258, -.4318, -.2366,
     2 -.1074, 0.0000,  .0969,  .1761,  .2304,  .3010,  .3522,  .4624,
     3  .5563,  .6435,  .7243,  .7924,  .8573,  .9191,  .9731, 1.0253,
     4 1.0719, 1.1173, 1.1614, 1.2095, 1.2480, 1.2900, 1.3263, 1.3617,
     5 1.3979, 1.4393, 1.4698, 1.4983, 1.5314, 1.5682, 1.6021, 1.6335,
     6 1.6721, 1.7076, 1.7482, 1.7924, 1.8325, 1.8865, 1.9395, 2.0000,
     7 2.0607, 2.1206, 2.1903, 2.2552, 2.3385, 2.4313, 2.5185, 2.6435,
     8 2.7853, 2.9777, 3.1072, 3.2553, 3.3617, 3.4771, 3.5563, 3.6233,
     9 3.7076, 3.8325, 3.9345/
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE AEREXT (V)
C
C     INTERPOLATES AEROSOL EXTINCTION AND ABSORPTION COEFFICIENT
C        FOR THE WAVENUMBER, V.
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,IBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      COMMON /AER/ EXTV(4),ABSV(4)
      DO 5 I=1,4
      EXTV(I)=0.
      ABSV(I)=0.
    5 CONTINUE
      IF (IHAZE.EQ.0) RETURN
      ALAM=1.0E+4/V
      DO 10 N=1,40
      XD=ALAM-VX2(N)
      IF (XD) 15,15,10
   10 CONTINUE
      N=40
   15 VXD=VX2(N)-VX2(N-1)
      DO 20 I=1,4
      EXTV(I)=(EXTC(I,N)-EXTC(I,N-1))*XD/VXD+EXTC(I,N)
      ABSV(I)=(ABSC(I,N)-ABSC(I,N-1))*XD/VXD+ABSC(I,N)
   20 CONTINUE
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE HNO3 (V,HABS)
C
C     HNO3  STATISTICAL BAND PARAMETERS
C
      DIMENSION H1(15), H2(16), H3(13)
C     ARRAY H1 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM  850 TO 920 CM-1
      DATA H1/2.197,3.911,6.154,8.150,9.217,9.461,11.56,11.10,11.17,12.4
     10,10.49,7.509,6.136,4.899,2.866/
C     ARRAY H2 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1275 TO1350 CM-1
      DATA H2/2.828,4.611,6.755,8.759,10.51,13.74,18.00,21.51,23.09,21.6
     18,21.32,16.82,16.42,17.87,14.86,8.716/
C     ARRAY H3 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1675 TO1735 CM-1
      DATA H3/5.003,8.803,14.12,19.83,23.31,23.58,23.22,21.09,26.99,25.8
     14,24.79,17.68,9.420/
      HABS=0.
      IF (V.GE.850.0.AND.V.LE.920.0) GO TO 5
      IF (V.GE.1275.0.AND.V.LE.1350.0) GO TO 10
      IF (V.GE.1675.0.AND.V.LE.1735.0) GO TO 15
      RETURN
    5 I=(V-845.)/5.
      HABS=H1(I)
      RETURN
   10 I=(V-1270.)/5.
      HABS=H2(I)
      RETURN
   15 I=(V-1670.)/5.
      HABS=H3(I)
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C1DTA (C1L,L)
C         WATER VAPOR
C     C1 LOCATION  1     V =  350  CM-1
C     C1 LOCATION  1770 V =  9195  CM-1
C     C1 LOCATION  1771 V =  9875  CM-1
C     C1 LOCATION  2355 V =  12795  CM-1
C     C1 LOCATION  2356 V =  12350  CM-1
C     C1 LOCATION  2580 V =  14520  CM-1
      COMMON /C1/C1(2580)
      DATA(C1(I),I=   1, 190)/
     1 3.93, 3.72, 3.54, 3.42, 3.37, 3.37, 3.36, 3.33, 3.25, 3.13,
     2 3.02, 2.96, 2.97, 3.00, 3.08, 3.12, 3.08, 3.03, 3.00, 3.01,
     3 3.03, 3.07, 3.05, 3.01, 2.94, 2.83, 2.71, 2.62, 2.58, 2.57,
     4 2.62, 2.67, 2.72, 2.71, 2.60, 2.46, 2.35, 2.26, 2.22, 2.23,
     5 2.19, 2.17, 2.17, 2.20, 2.26, 2.34, 2.42, 2.39, 2.20, 2.01,
     6 1.92, 1.83, 1.78, 1.79, 1.81, 1.84, 1.83, 1.80, 1.71, 1.51,
     7 1.39, 1.30, 1.25, 1.18, 1.19, 1.18, 1.21, 1.33, 1.47, 1.53,
     8 1.54, 1.36, 1.12,  .89,  .69,  .49,  .60,  .71,  .79,  .99,
     9  .86,  .73,  .53,  .43,  .51,  .52,  .67,  .73,  .80,  .83,
     $  .80,  .63,  .47,  .32, -.08, -.21, -.29, -.21, -.01,  .08,
     $  .16,  .09, -.03, -.21, -.37, -.35, -.30, -.31, -.37, -.42,
     $ -.48, -.42, -.40, -.39, -.43, -.77, -.83, -.88, -.79, -.60,
     $ -.50, -.42, -.39, -.38, -.37, -.40, -.51, -.67, -.82, -.58,
     $ -.40, -.32, -.21, -.09, -.18, -.16, -.19, -.28, -.33, -.35,
     $ -.28, -.22, -.10, -.05, -.11, -.13, -.27, -.27, -.18, -.06,
     $  .11,  .23,  .26,  .19,  .11, 0.00, -.09,  .02,  .08,  .12,
     $  .22,  .28,  .39,  .54,  .68,  .75,  .79,  .79,  .71,  .69,
     $  .76,  .88, 1.01, 1.16, 1.18, 1.14, 1.05, 1.02, 1.11, 1.23,
     $ 1.41, 1.75, 1.83, 1.99, 2.05, 2.03, 2.00, 1.96, 1.90, 1.86/
      DATA(C1(I),I= 191, 380)/
     1 1.91, 2.08, 2.24, 2.41, 2.63, 2.68, 2.67, 2.73, 2.79, 2.81,
     2 2.91, 2.93, 3.02, 3.16, 3.23, 3.30, 3.34, 3.43, 3.57, 3.59,
     3 3.59, 3.58, 3.57, 3.61, 3.71, 3.71, 3.69, 3.64, 3.60, 3.68,
     4 3.80, 3.95, 4.05, 4.05, 4.02, 3.99, 3.96, 4.01, 4.13, 4.22,
     5 4.35, 4.49, 4.58, 4.62, 4.63, 4.61, 4.57, 4.56, 4.56, 4.53,
     6 4.49, 4.46, 4.40, 4.28, 4.14, 3.92, 3.63, 3.35, 3.16, 3.10,
     7 3.24, 3.47, 3.66, 3.80, 3.93, 4.00, 4.04, 4.15, 4.23, 4.31,
     8 4.35, 4.31, 4.23, 4.20, 4.24, 4.28, 4.35, 4.42, 4.42, 4.44,
     9 4.46, 4.40, 4.30, 4.22, 4.13, 4.07, 4.12, 4.19, 4.22, 4.23,
     $ 4.16, 4.04, 3.99, 3.94, 3.93, 3.91, 3.86, 3.83, 3.80, 3.78,
     $ 3.70, 3.54, 3.40, 3.30, 3.31, 3.42, 3.52, 3.52, 3.49, 3.41,
     $ 3.21, 3.14, 3.10, 3.08, 3.11, 2.98, 2.88, 2.78, 2.74, 2.76,
     $ 2.77, 2.76, 2.82, 2.85, 2.86, 2.75, 2.64, 2.60, 2.61, 2.64,
     $ 2.56, 2.49, 2.37, 2.25, 2.14, 2.08, 2.11, 2.20, 2.31, 2.28,
     $ 2.15, 2.06, 1.98, 2.03, 2.05, 1.96, 1.84, 1.72, 1.64, 1.59,
     $ 1.57, 1.57, 1.60, 1.63, 1.51, 1.38, 1.07,  .91,  .87,  .92,
     $ 1.04, 1.01,  .92,  .84,  .92,  .97, 1.01, 1.06, 1.10, 1.06,
     $ 1.01,  .91,  .79,  .55,  .47,  .41,  .39,  .38,  .34,  .33,
     $  .36,  .43,  .48,  .45,  .38,  .27,  .21,  .22,  .29,  .37/
      DATA(C1(I),I= 381, 570)/
     1  .38,  .37,  .29,  .19,  .13,  .11,  .03, -.05, -.12, -.24,
     2 -.31, -.39, -.43, -.50, -.59, -.68, -.73, -.80, -.92,-1.06,
     3-1.14,-1.22,-1.27,-1.28,-1.33,-1.32,-1.43,-1.51,-1.63,-1.74,
     4-1.82,-1.98,-2.09,-2.21,-2.21,-2.24,-2.27,-2.36,-2.51,-2.65,
     5-2.70,-2.63,-2.57,-2.56,-2.59,-2.67,-2.69,-2.67,-2.68,-2.62,
     6-2.52,-2.42,-2.29,-2.14,-2.00,-1.87,-1.71,-1.51,-1.39,-1.27,
     7-1.12,-1.01, -.89, -.75, -.68, -.57, -.47, -.42, -.32, -.27,
     8 -.26, -.19, -.13, -.11, -.01,  .05,  .08,  .17,  .25,  .31,
     9  .41,  .43,  .44,  .43,  .36,  .35,  .31,  .25,  .25,  .22,
     $  .21,  .33,  .49,  .65,  .76,  .71,  .51,  .30,  .13,  .10,
```

```
$  .17,  .24,  .31,  .38,  .45,  .51,  .56,  .60,  .63,  .62,       C10
$  .63,  .64,  .66,  .69,  .76,  .75,  .74,  .70,  .62,  .53,       C10
$  .46,  .39,  .30,  .37,  .38,  .42,  .47,  .50,  .58,  .69,       C10
$  .67,  .62,  .64,  .68,  .76,  .90, 1.11, 1.13, 1.10,  .97,       C10
$  .98, 1.17, 1.38, 1.52, 1.70, 1.76, 1.84, 1.92, 1.90, 1.87,       C10
$ 1.91, 2.02, 2.17, 2.10, 2.18, 2.22, 2.25, 2.03, 2.01, 1.77,       C10
$ 1.93, 2.19, 2.28, 2.14, 2.15, 2.22, 2.01, 2.14, 2.26, 2.36,       C10
$ 2.51, 2.66, 2.73, 2.68, 2.69, 2.64, 2.22, 1.95, 1.61, 1.11,       C10
$  .88,  .83,  .89, 1.20, 1.62, 1.82, 1.99, 2.01, 2.14, 2.16/       C10
 DATA(C1(I),I= 571, 760)/                                           C10
1 2.21, 2.30, 2.38, 2.42, 2.50, 2.51, 2.49, 2.46, 2.42, 2.37,       C10
2 2.37, 2.33, 2.31, 2.43, 2.56, 2.61, 2.63, 2.60, 2.50, 2.38,       C10
3 2.41, 2.34, 2.31, 2.32, 2.40, 2.27, 2.32, 2.22, 2.09, 2.08,       C10
4 2.17, 2.41, 2.77, 2.68, 2.49, 2.29, 2.23, 2.42, 2.61, 2.58,       C10
5 2.49, 2.40, 2.39, 2.51, 2.60, 2.68, 2.68, 2.70, 2.82, 2.83,       C10
6 2.82, 2.81, 2.84, 2.86, 2.91, 2.96, 3.03, 3.08, 3.21, 3.30,       C10
7 3.40, 3.52, 3.49, 3.46, 3.51, 3.54, 3.56, 3.55, 3.57, 3.61,       C10
8 3.71, 3.80, 3.92, 3.99, 4.06, 4.02, 4.06, 4.12, 4.28, 4.30,       C10
9 4.22, 4.32, 4.42, 4.53, 4.64, 4.55, 4.40, 4.28, 4.32, 4.38,       C10
$ 4.37, 4.24, 4.13, 4.14, 4.20, 4.25, 4.32, 4.35, 4.31, 4.27,       C10
$ 4.25, 4.27, 4.31, 4.36, 4.41, 4.52, 4.59, 4.71, 4.79, 4.81,       C10
$ 4.73, 4.61, 4.42, 4.28, 4.08, 4.00, 3.88, 3.86, 3.92, 3.98,       C10
$ 4.12, 4.18, 4.31, 4.37, 4.42, 4.50, 4.53, 4.56, 4.59, 4.61,       C10
$ 4.61, 4.59, 4.53, 4.49, 4.44, 4.41, 4.40, 4.34, 4.30, 4.26,       C10
$ 4.09, 3.98, 3.87, 3.78, 3.77, 3.79, 3.75, 3.72, 3.62, 3.56,       C10
$ 3.51, 3.48, 3.32, 3.18, 3.07, 2.96, 2.87, 2.80, 2.68, 2.58,       C10
$ 2.59, 2.51, 2.59, 2.57, 2.50, 2.42, 2.32, 2.20, 2.12, 2.00,       C10
$ 1.92, 1.79, 1.63, 1.60, 1.69, 1.78, 2.04, 2.00, 1.81, 1.70,       C10
$ 1.63, 1.61, 1.60, 1.49, 1.14, 1.35, 1.64, 1.69, 1.70, 1.59/       C10
 DATA(C1(I),I= 761, 950)/                                           C10
1 1.45, 1.29, 1.19, 1.08, 1.02, 1.04, 1.10, 1.16, 1.20, 1.23,       C10
2 1.22, 1.08, 1.08, 1.06,  .89,  .93,  .73,  .58,  .54,  .77,       C10
3  .81,  .74,  .71,  .57,  .49,  .43,  .38,  .12,  .10,  .20,       C10
4  .41,  .37,  .31,  .11, -.13, -.21, -.32, -.36, -.39, -.33,       C10
5 -.39, -.45, -.50, -.56, -.62, -.68, -.77, -.84, -.91,-1.00,       C10
6-1.11,-1.19,-1.28,-1.31,-1.39,-1.43,-1.48,-1.52,-1.57,-1.60,       C10
7-1.61,-1.60,-1.58,-1.51,-1.42,-1.32,-1.26,-1.16,-1.00, -.83,       C10
8 -.71, -.61, -.52, -.43, -.36, -.30, -.21, -.19, -.17, -.15,       C10
9 -.13, -.17, -.19, -.12, -.06, -.01, 0.00, -.11, -.23, -.32,       C10
$ -.44, -.51, -.48, -.47, -.42, -.40, -.40, -.39, -.37, -.35,       C10
$ -.48, -.75,-1.13,-1.58,-1.80,-1.66,-1.52,-1.35,-1.19,-1.02,       C10
$ -.88, -.66, -.65, -.63, -.62, -.66, -.73, -.79, -.88, -.84,       C10
$ -.70, -.59, -.43, -.39, -.50, -.61, -.74, -.79, -.76, -.69,       C10
$ -.62, -.59, -.52, -.48, -.48, -.42, -.39, -.38, -.33, -.29,       C10
$ -.26, -.23, -.22, -.28, -.37, -.50, -.60, -.60, -.51, -.46,       C10
$ -.42, -.43, -.45, -.35, -.24, -.14, -.08, -.08, 0.00,  .11,       C10
$  .32,  .43,  .42,  .32,  .23,  .22,  .28,  .45,  .55,  .62,       C10
$  .65,  .71,  .75,  .80,  .83,  .85,  .87,  .90,  .93, 1.00,       C10
$ 1.04, 1.15, 1.22, 1.32, 1.31, 1.32, 1.33, 1.48, 1.78, 1.87/       C10
 DATA(C1(I),I= 951,1140)/                                           C10
1 2.01, 1.92, 1.86, 1.89, 1.92, 1.98, 2.03, 2.39, 2.31, 2.40,       C10
2 2.70, 2.71, 2.76, 2.78, 2.70, 2.77, 3.08, 2.94, 3.05, 2.94,       C10
3 3.23, 3.20, 3.19, 3.32, 3.11, 3.41, 3.31, 3.36, 3.46, 3.36,       C10
4 3.39, 3.59, 3.41, 3.22, 3.19, 2.98, 2.78, 2.98, 3.02, 2.82,       C10
5 2.98, 2.86, 2.92, 2.92, 3.05, 3.22, 3.60, 3.78, 3.81, 3.96,       C10
6 3.76, 3.62, 3.34, 3.08, 3.31, 3.16, 3.37, 3.41, 3.30, 3.33,       C10
7 3.33, 3.51, 3.48, 3.43, 3.52, 3.31, 3.40, 3.58, 3.61, 3.49,       C10
8 3.46, 3.42, 3.19, 3.18, 3.30, 3.00, 2.99, 3.21, 3.11, 3.14,       C10
9 3.10, 2.72, 2.81, 2.95, 2.69, 2.73, 2.72, 2.47, 2.51, 2.60,       C10
$ 2.42, 2.37, 2.73, 1.91, 1.87, 1.81, 1.78, 1.53, 1.51, 1.62,       C10
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$ 1.59, 1.50, 1.42, 1.32, 1.22, 1.12, 1.08, 1.02,  .97,  .92,          C1D 1210
$  .90,  .87,  .84,  .82,  .79,  .78,  .76,  .75,  .72,  .71,          C1D 1220
$  .71,  .70,  .69,  .67,  .61,  .59,  .52,  .48,  .41,  .39,          C1D 1230
$  .38,  .33,  .32,  .30,  .30,  .30,  .29,  .28,  .27,  .26,          C1D 1240
$  .25,  .23,  .22,  .21,  .20,  .18,  .14,  .13,  .06,  .01,          C1D 1250
$ -.03, -.07, -.11, -.16, -.21, -.24, -.29, -.32, -.38, -.41,          C1D 1260
$ -.45, -.50, -.54, -.61, -.69, -.76, -.84, -.90, -.97,-1.01,          C1D 1270
$-1.10,-1.13,-1.19,-1.22,-1.28,-1.30,-1.33,-1.36,-1.39,-1.43,          C1D 1280
$-1.48,-1.50,-1.52,-1.57,-1.61,-1.66,-1.70,-1.72,-1.78,-1.81/          C1D 1290
 DATA(C1(I),I=1141,1330)/                                              C1D 1300
1-1.89,-1.92,-2.00,-2.08,-2.16,-2.24,-2.31,-2.40,-2.48,-2.54,          C1D 1310
2-2.61,-2.71,-2.83,-2.95,-3.10,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1320
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1330
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1340
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1350
6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1360
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1370
8-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1380
9-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1390
$-3.78,-3.33,-3.01,-2.82,-2.68,-2.49,-2.30,-2.13,-2.00,-1.81,          C1D 1400
$-1.60,-1.41,-1.13, -.90, -.79, -.63, -.48, -.36, -.28, -.16,          C1D 1410
$ -.06,  .08,  .20,  .28,  .41,  .54,  .69,  .80,  .92, 1.04,          C1D 1420
$ 1.19, 1.19, 1.01,  .98, 1.02, 1.19, 1.29, 1.30, 1.29, 1.38,          C1D 1430
$ 1.19, 1.39, 1.42, 1.43, 1.70, 1.62, 1.54, 1.41, 1.53, 1.86,          C1D 1440
$ 1.96, 1.97, 2.02, 2.01, 1.94, 1.94, 1.83, 2.03, 2.21, 2.42,          C1D 1450
$ 2.30, 2.16, 2.02, 2.02, 2.02, 2.13, 1.90, 1.71, 2.01, 1.56,          C1D 1460
$ 1.56, 1.51, 1.30, 1.63, 1.64, 1.67, 1.70, 2.22, 2.39, 2.38,          C1D 1470
$ 2.30, 1.93, 2.39, 2.49, 2.52, 2.57, 2.21, 2.18, 2.40, 2.41,          C1D 1480
$ 2.45, 2.51, 2.23, 2.49, 2.30, 2.61, 2.72, 2.52, 2.63, 2.56/          C1D 1490
 DATA(C1(I),I=1331,1520)/                                              C1D 1500
1 2.51, 2.70, 2.62, 2.52, 2.80, 2.74, 2.79, 2.74, 2.70, 2.88,          C1D 1510
2 2.81, 2.72, 2.76, 2.84, 2.92, 2.98, 2.88, 2.88, 3.02, 3.08,          C1D 1520
3 3.26, 3.03, 3.14, 3.28, 3.03, 3.11, 3.15, 3.30, 3.31, 3.22,          C1D 1530
4 3.00, 3.06, 3.34, 3.40, 3.37, 3.32, 3.08, 3.09, 3.09, 3.61,          C1D 1540
5 3.07, 3.07, 3.31, 3.21, 3.31, 3.67, 3.58, 3.79, 3.70, 3.49,          C1D 1550
6 3.39, 3.11, 3.13, 3.01, 3.10, 3.01, 3.18, 3.32, 3.43, 3.35,          C1D 1560
7 3.40, 3.39, 3.39, 3.51, 3.54, 3.42, 3.50, 3.67, 3.59, 3.63,          C1D 1570
8 3.66, 3.48, 3.39, 3.29, 3.31, 3.41, 3.23, 3.32, 3.12, 2.91,          C1D 1580
9 2.91, 2.75, 2.78, 2.72, 2.62, 2.58, 2.32, 2.22, 2.00, 1.97,          C1D 1590
$ 1.68, 1.62, 1.64, 1.53, 1.56, 1.51, 1.52, 1.48, 1.42, 1.42,          C1D 1600
$ 1.40, 1.41, 1.43, 1.56, 1.52, 1.51, 1.52, 1.39, 1.39, 1.30,          C1D 1610
$ 1.09, 1.16, 1.21, 1.20, 1.22, 1.20, 1.18, 1.20, 1.19, 1.17,          C1D 1620
$ 1.10, 1.10, 1.09, 1.10, 1.11, 1.04,  .98,  .90,  .86,  .90,          C1D 1630
$  .90,  .90,  .86,  .71,  .79,  .70,  .71,  .67,  .62,  .53,          C1D 1640
$  .42,  .31,  .20,  .01, -.08, -.17, -.26, -.35, -.44, -.53,          C1D 1650
$ -.63, -.73, -.83, -.93,-1.04,-1.14,-1.24,-1.34,-1.44,-1.54,          C1D 1660
$-1.64,-1.74,-1.84,-1.94,-2.04,-2.14,-2.24,-2.34,-2.44,-2.54,          C1D 1670
$-2.64,-2.74,-2.84,-2.94,-3.04,-3.14,-3.24,-3.34,-3.44,-3.54,          C1D 1680
$-3.64,-3.74,-3.84,-3.94,-4.04,-5.00,-5.00,-5.00,-5.00,-5.00/          C1D 1690
 DATA(C1(I),I=1521,1710)/                                              C1D 1700
1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1710
2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1720
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1730
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1740
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1750
6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1760
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 1770
8-4.15,-4.06,-3.97,-3.88,-3.79,-3.70,-3.61,-3.52,-3.43,-3.34,          C1D 1780
9-3.25,-3.16,-3.07,-2.98,-2.89,-2.80,-2.71,-2.62,-2.53,-2.44,          C1D 1790
$-2.35,-2.26,-2.18,-2.09,-2.00,-1.91,-1.82,-1.73,-1.64,-1.55,          C1D 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$-1.46,-1.37,-1.28,-1.19,-1.10,-1.01, -.92, -.83, -.74, -.65,
$ -.56, -.47, -.38, -.29, -.20, -.14, -.09, -.02,  .03,  .10,
$  .17,  .22,  .30,  .35,  .41,  .45,  .42,  .40,  .43,  .46,
$  .50,  .59,  .71,  .84,  .93, 1.01, 1.06, 1.07, 1.02, 1.01,
$ 1.12, 1.23, 1.24, 1.28, 1.34, 1.43, 1.52, 1.56, 1.59, 1.56,
$ 1.51, 1.61, 1.50, 1.70, 1.82, 1.92, 1.94, 1.89, 1.81, 1.45,
$ 1.30, 1.28, 1.43, 1.50, 1.49, 1.55, 1.48, 1.32, 1.39, 1.53,
$ 1.82, 2.23, 2.61, 2.51, 2.20, 1.86, 1.61, 1.19, 1.32, 1.52,
$ 1.70, 1.90, 2.01, 1.92, 1.91, 2.12, 2.10  2.  , 2.18, 1.99/
 DATA(C1(I),I=1711,1900)/
1 2.11, 2.28, 2.21, 2.13, 2.00, 1.91, 1.92, 1.97, 1.88, 1.91,
2 1.91, 1.92, 1.93, 1.74, 1.61, 1.58, 1.27, 1.20, 1.18, 1.11,
3  .99,  .86,  .71,  .60,  .44,  .31,  .19,  .03, -.07, -.21,
4 -.35, -.49, -.64, -.79, -.94,-1.11,-1.24,-1.41,-1.57,-1.73,
5-1.91,-2.09,-2.27,-2.45,-2.63,-2.81,-2.99,-3.18,-3.37,-3.56,
6-3.75,-3.94,-4.13,-4.31,-4.49,-4.66,-4.83,-4.99,-5.14,-5.28,
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.68,-4.26,
8-3.89,-3.57,-3.32,-3.11,-2.91,-2.89,-2.79,-2.74,-2.63,-2.47,
9-2.29,-2.20,-2.17,-2.23,-2.27,-2.32,-2.12,-2.08,-2.07,-2.07,
$-2.07,-1.98,-1.77,-1.70,-1.63,-1.60,-1.59,-1.43,-1.21,-1.15,
$-1.09,-1.13,-1.29,-1.19, -.98, -.93, -.87, -.91, -.88, -.71,
$ -.62, -.59, -.58, -.63, -.58, -.39, -.22, -.14, -.06, -.01,
$ -.01, -.08, -.20, -.16, -.02,  .18,  .32,  .42,  .37,  .23,
$  .12,  .15,  .28,  .43,  .59,  .58,  .53,  .44,  .39,  .38,
$  .35,  .23,  .26,  .19,  .08,  .10,  .18,  .27,  .38,  .43,
$  .32,  .37,  .58,  .64,  .87,  .98, 1.00, 1.02, 1.13, 1.08,
$ 1.08, 1.16, 1.16, 1.30, 1.41, 1.40, 1.32, 1.32, 1.37, 1.42,
$ 1.50, 1.42, 1.38, 1.36, 1.38, 1.49, 1.63, 1.62, 1.62, 1.70,
$ 1.68, 1.60, 1.56, 1.56, 1.63, 1.64, 1.56, 1.49, 1.49, 1.52/
 DATA(C1(I),I=1901,2090)/
1 1.58, 1.62, 1.62, 1.61, 1.61, 1.62, 1.63, 1.71, 1.72, 1.70,
2 1.70, 1.67, 1.62, 1.66, 1.70, 1.67, 1.56, 1.49, 1.42, 1.38,
3 1.26, 1.20, 1.13, 1.14, 1.19, 1.29, 1.50, 1.72, 1.86, 1.78,
4 1.82, 1.88, 1.82, 1.89, 1.99, 2.00, 2.14, 2.04, 2.02, 2.02,
5 1.98, 1.90, 1.83, 1.81, 1.72, 1.69, 1.59, 1.50, 1.36, 1.20,
6  .98,  .63,  .43,  .29,  .16,  .05,  .02,  .03,  .03,  .01,
7 -.08, -.18, -.20, -.11, -.06, -.03, -.14, -.21, -.08, -.06,
8  .10,  .18,  .11,  .72,  .42,  .44,  .38,  .28,  .42,  .43,
9  .41,  .33,  .32,  .41,  .50,  .46,  .31,  .18,  .08,  .20,
$  .21,  .34,  .36,  .28,  .35,  .39,  .42,  .38,  .32,  .30,
$  .16, -.01, -.23, -.41, -.52, -.48, -.58, -.61, -.48, -.23,
$ -.03,  .21,  .36,  .39,  .47,  .44,  .40,  .51,  .59,  .53,
$  .69,  .57,  .48,  .52,  .62,  .59,  .55,  .50,  .32,  .26,
$  .11, -.08, -.10, -.16, -.43, -.62, -.88,-1.09,-1.16,-1.31,
$-1.45,-1.49,-1.78,-1.91,-2.01,-1.97,-1.97,-1.97,-1.97,-2.26,
$-2.20,-2.01,-1.99,-2.00,-2.04,-2.37,-2.49,-2.44,-2.36,-2.32,
$-2.19,-2.10,-2.25,-2.16,-2.36,-2.44,-2.40,-2.49,-2.48,-2.43,
$-2.40,-2.36,-2.40,-2.49,-2.59,-2.68,-2.89,-3.28,-3.51,-3.74,
$-3.97,-4.20,-4.43,-4.66,-4.89,-5.00,-5.00,-5.00,-5.00,-5.00/
 DATA(C1(I),I=2091,2280)/
1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
6-5.00,-5.00,-5.00,-5.00,-5.00,-3.71,-3.56,-3.40,-3.21,-3.06,
7-2.90,-2.74,-2.60,-2.46,-2.32,-2.17,-2.03,-1.87,-1.79,-1.74,
8-1.83,-1.82,-1.71,-1.59,-1.49,-1.46,-1.46,-1.49,-1.49,-1.25,
9-1.24,-1.08, -.90,-1.06, -.91, -.91,-1.01, -.99, -.87, -.92,
$ -.79, -.42, -.54, -.38, -.42, -.48, -.34, -.27, -.17, -.28,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     $ -.38, -.22, -.30, -.08, -.01, -.20,  .06,  .10,  .06,  .14,          C1D 2410
     $ -.12, -.02, -.07, -.13, -.11, -.10, -.06, -.05, -.04, -.10,          C1D 2420
     $ -.04, -.06, -.21, -.38, -.61, -.40, -.31, -.42, -.58, -.57,          C1D 2430
     $ -.54, -.24,  .11,  .51,  .81,  .79,  .62,  .26, -.31, -.67,          C1D 2440
     $ -.80, -.88, -.50, -.39, -.10,  .09,  .07,  .08,  .16,  .21,          C1D 2450
     $  .13,  .32,  .35,  .51,  .60,  .51,  .51,  .40,  .40,  .43,          C1D 2460
     $  .42,  .33,  .43,  .34,  .22,  .13, -.11, -.31, -.31, -.41,          C1D 2470
     $ -.41, -.39, -.53, -.69, -.84, -.88,-1.01,-1.10,-1.19,-1.29,          C1D 2480
     $-1.45,-1.49,-1.67,-1.67,-1.51,-1.66,-1.60,-1.69,-1.83,-1.51/          C1D 2490
      DATA (C1(I),I=2281,2470)/                                             C1D 2500
     1-1.42,-1.40,-1.24,-1.38,-1.31,-1.30,-1.30,-1.28,-1.39,-1.33,          C1D 2510
     2-1.40,-1.35,-1.37,-1.39,-1.41,-1.49,-1.48,-1.56,-1.47,-1.46,          C1D 2520
     3-1.41,-1.42,-1.48,-1.41,-1.31,-1.15,-1.13,-1.20,-1.41,-1.88,          C1D 2530
     4-2.08,-2.08,-2.22,-2.35,-2.35,-1.98,-1.92,-1.78,-1.57,-1.69,          C1D 2540
     5-1.70,-1.70,-1.66,-1.94,-1.50,-1.56,-1.42,-1.29,-1.38,-1.28,          C1D 2550
     6-1.48,-1.58,-1.44,-1.53,-1.48,-1.48,-1.58,-1.58,-1.69,-1.79,          C1D 2560
     7-2.00,-2.16,-1.99,-2.23,-2.04,-2.04,-2.39,-2.74,-3.09,-3.44,          C1D 2570
     8-3.79,-4.14,-4.49,-4.84,-5.19,-2.46,-2.26,-1.99,-2.01,-2.14,          C1D 2580
     9-2.31,-2.15,-2.01,-1.99,-2.14,-2.41,-2.12,-1.99,-1.84,-1.79,          C1D 2590
     $-1.71,-1.78,-1.72,-1.68,-1.78,-1.52,-1.38,-1.29,-1.22, -.91,          C1D 2600
     $ -.90,-1.01, -.76, -.90, -.90, -.90,-1.19,-1.00, -.79, -.68,          C1D 2610
     $ -.68, -.73, -.85, -.85, -.61, -.61, -.48, -.51, -.92, -.83,          C1D 2620
     $ -.61, -.41, -.29, -.29, -.61, -.74, -.19, -.18, 0.00,  .19,          C1D 2630
     $ -.10,  .20,  .20,  .02,  .20, -.01,  .18,  .28,  .11, 0.00,          C1D 2640
     $ -.37, -.10,  .02,  .16,  .20, 0.00,  .09,  .09,  .09,  .07,          C1D 2650
     $  .22,  .11,  .11,  .21,  .09,  .21,  .20,  .37,  .28,  .07,          C1D 2660
     $  .09, -.29, -.69, -.69, -.74, -.88,-1.01, -.86, -.54, -.19,          C1D 2670
     $  .19,  .27,  .21,  .29,  .28,  .29,  .52,  .54,  .51,  .60,          C1D 2680
     $  .40,  .49,  .48,  .46,  .49,  .27,  .06, -.33, -.81,-1.17/          C1D 2690
      DATA(C1(I),I=2471,2580)/                                              C1D 2700
     1-1.11,-1.37,-1.52,-1.54,-1.94,-2.06,-2.06,-2.14,-1.96,-2.00,          C1D 2710
     2-2.00,-2.08,-2.23,-2.31,-2.31,-2.53,-2.31,-2.31,-2.31,-2.28,          C1D 2720
     3-2.34,-2.34,-1.91,-1.82,-1.69,-1.56,-1.84,-1.91,-1.75,-1.83,          C1D 2730
     4-1.76,-1.54,-1.98,-1.80,-1.68,-1.69,-1.56,-1.60,-1.71,-1.36,          C1D 2740
     5-1.36,-1.44,-1.48,-1.40,-1.48,-1.36,-1.45,-1.49,-1.85,-1.39,          C1D 2750
     6-1.23,-1.19,-1.18,-1.34,-1.36,-1.23,-1.23,-1.37,-1.30,-1.40,          C1D 2760
     7-1.28,-1.27,-1.37,-1.32,-1.32,-1.22,-1.28,-1.38,-1.69,-2.07,          C1D 2770
     8-2.42,-2.58,-2.58,-2.80,-2.58,-2.47,-1.88,-1.60,-1.26,-1.16,          C1D 2780
     9-1.23,-1.10,-1.23,-1.10, -.83, -.80, -.80, -.80, -.98, -.97,          C1D 2790
     $ -.97, -.91, -.92,-1.13,-1.24,-1.50,-1.89,-2.18,-2.32,-2.63,          C1D 2800
     $-3.91,-4.20,-4.49,-4.78,-5.07,-5.07,-5.07,-5.07,-5.07,-5.07/          C1D 2810
      C1L=C1(L)                                                             C1D 2820
      RETURN                                                                C1D 2830
      END                                                                   C1D 2840
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C2CTA (C2L,L)
C        UNIFORMLY MIXED GASES
C     C2 LOCATION  1     V =  500     CM-1
C     C2 LOCATION  1515 V =  8070     CM-1
C     C2 LOCATION  1516 V =  12950     CM-1
C     C2 LOCATION  1575 V =  13245   CM-1
      COMMON/C2/ C2(1575)
      DATA(C2(I),I=   1, 190)/
     1-4.25,-3.70,-3.20,-2.75,-1.90,-1.73,-1.51,-1.29,-1.11, -.91,
     2 -.71, -.51, -.30, -.36,  .22,  .49,  .76, 1.08, 1.29, 1.56,
     3 1.76, 1.91, 2.08, 2.23, 2.36, 2.51, 2.72, 2.90, 3.12, 3.37,
     4 3.56, 3.69, 3.79, 3.86, 3.88, 3.86, 3.73, 3.58, 3.38, 3.17,
     5 2.86, 2.73, 2.52, 2.31, 2.17, 2.01, 1.89, 1.77, 1.63, 1.47,
     6 1.21,  .92,  .53,  .23, -.17, -.53, -.74, -.81, -.84, -.88,
     7-1.00,-1.18,-1.42,-1.61,-1.86,-2.10,-2.29,-2.51,-2.72,-2.91,
     8-3.14,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     9-5.00,-2.68,-2.47,-2.19,-1.97,-1.71,-1.58,-1.32,-1.21,-1.13,
     $-1.09,-1.11,-1.10,-1.09,-1.01,-1.01,-1.11,-1.33,-1.66,-2.13,
     $-2.51,-2.67,-2.71,-2.39,-2.09,-1.78,-1.59,-1.33,-1.18,-1.01,
     $ -.96, -.91, -.90, -.87, -.80, -.79, -.86,-1.07,-1.28,-1.69,
     $-2.11,-2.74,-3.09,-3.50,-3.03,-2.58,-2.23,-1.89,-1.54,-1.28,
     $-1.13,-1.11,-1.16,-1.20,-1.23,-1.21,-1.17,-1.12,-1.15,-1.19,
     $-1.20,-1.17,-1.02, -.89, -.68, -.42, -.24, -.01,  .18,  .40,
     $  .57,  .77,  .96, 1.07, 1.13, 1.11, 1.08, 1.15, 1.27, 1.33,
     $ 1.44, 1.40, 1.13,  .89,  .63,  .54,  .65,  .78,  .81,  .86,
     $  .87,  .68,  .47,  .14, -.12, -.48, -.92,-1.43,-1.89,-2.32,
     $-2.81,-5.00,-5.00,-5.00,-3.14,-2.47,-2.00,-1.71,-1.59,-1.61/
      DATA(C2(I),I= 191, 380)/
     1-1.69,-1.82,-1.87,-1.90,-1.94,-2.04,-2.10,-2.23,-2.32,-2.48,
     2-2.71,-2.88,-3.09,-2.99,-2.43,-2.00,-1.69,-1.42,-1.38,-1.49,
     3-1.70,-2.01,-2.41,-2.64,-2.63,-2.49,-2.38,-2.27,-2.16,-2.05,
     4-1.94,-1.83,-1.76,-1.71,-1.70,-1.72,-1.81,-1.92,-2.03,-2.27,
     5-2.61,-3.21,-4.01,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     8-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.30,-3.42,-3.17,-2.98,
     9-2.83,-2.71,-2.67,-2.67,-2.68,-2.58,-2.33,-2.01,-1.64,-1.32,
     $ -.97, -.76, -.63, -.59, -.60, -.63, -.69, -.87,-1.08,-1.26,
     $-1.53,-1.87,-1.91,-1.93,-2.02,-2.21,-2.48,-2.80,-3.08,-3.11,
     $-3.09,-2.93,-2.76,-2.39,-2.01,-1.69,-1.36, -.99, -.63, -.28,
     $ 0.00,  .08,  .11,  .12,  .12,  .07,  .01, -.08, -.23, -.40,
     $ -.51, -.53, -.57, -.60, -.61, -.73, -.81, -.95,-1.05,-1.02,
     $ -.91, -.68, -.41, -.09.  .16   .41,  .76, 1.00, 1.18, 1.39,
     $ 1.51, 1.58, 1.68, 1.71, 1.8 , 1.91, 2.02, 2.18, 2.32, 2.50,
     $ 2.61, 2.69, 2.81, 2.89, 2.96, 3.04, 3.14, 3.27, 3.41, 3.55,
     $ 3.72, 3.90, 4.03, 4.22, 4.42, 4.61, 4.71, 4.73, 4.65, 4.63,
     $ 4.72, 4.78, 4.79, 4.50, 3.62, 3.28, 2.79, 2.30, 1.86, 1.35/
      DATA(C2(I),I= 381, 570)/
     1  .62, -.24,-1.69,-2.18,-2.01,-1.79,-1.53,-1.32,-1.20,-1.15,
     2-1.12,-1.18,-1.25,-1.26,-1.20,-1.17,-1.20,-1.32,-1.54,-1.84,
     3-2.16,-2.30,-2.26,-2.01,-1.71,-1.36,-1.06, -.81, -.61, -.49,
     4 -.45, -.47, -.49, -.46, -.37, -.31, -.34, -.49, -.75,-1.11,
     5-1.43,-2.01,-2.60,-2.89,-2.87,-2.74,-2.51,-2.42,-2.38,-2.39,
     6-2.42,-2.46,-2.48,-2.49,-2.43,-2.43,-2.46,-2.53,-2.68,-2.74,
     7-2.82,-2.87,-2.83,-2.82,-2.79,-2.71,-2.66,-2.49,-2.40,-2.32,
     8-2.26,-2.23,-2.20,-2.09,-2.02,-1.96,-1.88,-1.84,-1.86,-1.86.
     9-1.87,-1.83,-1.79,-1.73,-1.68,-1.64,-1.69,-1.74,-1.79,-1.87,
     $-1.78,-1.63,-1.50,-1.37,-1.21,-1.00, -.83, -.69, -.53, -.41,
     $ -.30, -.19, -.09, -.04,  .02,  .10,  .16,  .18,  .23,  .26,
     $  .27,  .26,  .24,  .22,  .17,  .12,  .07, -.01, -.07, -.09,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$  .32,  .72,  .91, 1.12, 1.03,  .67,  .18, -.11, -.38, -.29,
$ -.17, -.08, 0.00,  .09,  .13,  .18,  .24,  .27,  .29,  .30,
$  .29,  .26,  .23,  .21,  .13,  .09,  .02, -.04, -.18, -.32,
$ -.51, -.72, -.98,-1.18,-1.50,-1.62,-1.81,-2.04,-2.29,-2.49,
$-2.62,-2.87,-3.03,-3.21,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.01,-3.38,-3.01,-2.63,
$-2.32,-2.09,-1.98,-1.94,-2.00,-2.14,-2.26,-2.20,-2.02,-1.82/
 DATA(C2(I),I= 571, 760)/
1-1.59,-1.43,-1.38,-1.46,-1.64,-1.90,-2.09,-2.54,-2.91,-3.28,
2-3.61,-3.72,-3.64,-3.50,-3.41,-3.37,-3.30,-3.16,-3.01,-2.76,
3-2.51,-2.20,-1.80,-1.49,-1.22, -.97, -.72, -.49, -.20,  .03,
4  .20,  .36,  .51,  .61,  .67,  .83, 1.00, 1.22, 1.38, 1.56,
5 1.70, 1.86, 2.01, 2.20, 2.31, 2.47, 2.61, 2.76, 2.92, 3.01,
6 3.05, 3.02, 2.98, 2.98, 3.01, 3.03, 2.97, 2.78, 2.44, 2.13,
7 1.83, 1.59, 1.49, 1.50, 1.67, 1.94, 2.22, 2.50, 2.71, 2.93,
8 3.12, 3.18, 3.17, 3.15, 3.21, 3.26, 3.19, 2.98, 2.69, 2.14,
9 1.70, 1.22,  .55, -.27,-1.09,-2.54,-3.00,-2.94,-2.78,-2.69,
$-2.61,-2.60,-2.63,-2.60,-2.57,-2.53,-2.57,-2.64,-2.77,-3.04,
$-3.38,-3.98,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.50,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-4.00,-3.73,-3.62,-3.59,-3.53,-3.56,-3.57,-3.53,-3.51,
$-3.45,-3.37,-3.26,-3.21,-3.18,-3.27,-3.36,-3.60,-3.96,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-4.62,-4.07,-3.89,-3.76,-3.67,-3.56,
$-3.42,-3.35,-3.26,-3.18,-3.14,-3.11,-3.09,-3.10,-3.12,-3.23,
$-3.30,-3.39,-3.37,-3.29,-3.14,-3.08,-3.00,-2.93,-2.89,-2.91/
 DATA(C2(I),I= 761, 950)/
1-3.00,-3.08,-3.16,-3.31,-3.48,-3.71,-3.98,-5.00,-5.00,-5.00,
2-5.00,-4.52,-3.98,-3.69,-3.42,-3.18,-2.95,-2.77,-2.51,-2.48,
3-2.41,-2.41,-2.40,-2.38,-2.34,-2.27,-2.21,-2.31,-2.48,-2.73,
4-3.21,-4.13,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
6-5.00,-5.00,-4.13,-4.12,-3.99,-3.96,-3.97,-3.73,-3.51,-3.29,
7-3.15,-2.99,-2.84,-2.73,-2.69,-2.68,-2.69,-2.65,-2.62,-2.59,
8-2.57,-2.62,-2.81,-3.04,-3.21,-3.39,-3.42,-3.36,-3.21,-3.03,
9-2.93,-2.80,-2.64,-2.52,-2.37,-2.28,-2.20,-2.13,-2.07,-2.02,
$-1.96,-1.88,-1.78,-1.63,-1.44,-1.31,-1.20,-1.08, -.98, -.94,
$ -.86, -.76, -.52, -.31, -.08,  .13,  .30,  .37,  .36,  .36,
$  .35,  .35,  .39,  .46,  .48,  .41,  .23, -.08, -.38, -.67,
$ -.88, -.96, -.98, -.87, -.67, -.36, -.12,  .14,  .44,  .68,
$  .90, 1.11, 1.19, 1.24, 1.25, 1.26, 1.27, 1.51, 1.59, 1.50,
$ 1.28,  .71,  .11, -.28, -.67,-1.32,-1.61,-1.58,-1.42,-1.18,
$ -.91, -.59, -.27, -.06,  .29,  .57,  .73,  .92,  .81,  .73,
$  .79,  .91, 1.01, 1.03,  .88,  .72,  .63,  .38,  .12, -.21,
$ -.47, -.67,-1.23,-1.67,-2.31,-2.76,-3.24,-3.49,-3.51,-3.47,
$-3.39,-3.37,-3.43,-3.53,-3.50,-3.36,-3.18,-3.07,-2.96,-3.08/
 DATA(C2(I),I= 951,1140)/
1-3.14,-3.12,-3.23,-3.07,-2.83,-2.47,-2.23,-2.07,-1.91,-1.78,
2-1.63,-1.46,-1.27,-1.23,-1.26,-1.40,-1.57,-1.98,-2.28,-2.87,
3-3.74,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
8-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
9-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-4.91,-4.79,-4.61,-4.49,-4.40,-4.29,-4.17,-3.90,
$-3.73,-3.59,-3.62,-3.72,-3.73,-3.69,-3.31,-3.12,-2.91,-2.63,
$-2.41,-2.27,-2.16,-2.11,-2.28,-2.29,-2.21,-2.06,-1.91,-1.99,
$-2.27,-2.59,-2.98,-3.35,-3.69,-3.79,-3.68,-3.53,-3.46,-3.39,
$-3.31,-3.18,-2.97,-2.69,-2.39,-2.11,-1.83,-1.58,-1.49,-1.22/
 DATA(C2(I),I=1141,1330)/
1-1.08, -.89, -.68, -.54, -.71, -.79, -.78, -.66, -.49, -.54,
2 -.86,-1.17,-2.08,-2.44,-3.46,-3.72,-3.74,-3.59,-3.22,-2.98,
3-2.52,-2.21,-1.64,-1.34,-1.08, -.86, -.72, -.61, -.70, -.72,
4 -.67, -.57, -.38, -.51, -.97,-1.36,-1.89,-2.74,-3.18,-4.21,
5-4.57,-4.62,-4.78,-4.87,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
6-4.93,-4.46,-3.99,-3.45,-2.99,-2.63,-2.30,-2.09,-2.02,-2.12,
7-2.18,-2.13,-2.04,-1.78,-1.83,-2.08,-2.28,-2.81,-3.01,-3.15,
8-3.22,-3.29,-3.58,-3.89,-4.46,-4.88,-5.00,-5.00,-5.00,-5.00,
9-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-4.81,-4.52,-4.11,-3.69,-3.09,-2.99,-2.91,-2.89,-3.19,-3.20,
$-3.36,-3.62,-3.89,-3.92,-3.73,-3.53,-3.37,-3.19,-3.02,-2.79,
$-2.52,-2.36,-2.24,-2.19,-2.32,-2.41,-2.29,-2.06,-2.00,-2.18,
$-2.47,-2.91,-3.57,-4.39,-5.00,-5.00,-5.00,-5.00,-5.00,-4.61,
$-4.19,-3.89,-3.57,-3.30,-3.02,-2.74,-2.51,-2.20,-1.98,-1.73,
$-1.57,-1.38,-1.21,-1.11, -.98, -.87, -.78, -.60, -.37, -.18,
$ -.04, -.04, -.06, -.16, -.18, -.19, -.23, -.45,-1.02,-1.97,
$-2.79,-3.71,-4.01,-4.20,-4.35,-4.58,-4.73,-4.81,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00/
 DATA(C2(I),I=1331,1520)/
1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
6-5.00,-5.00,-5.00,-4.71,-4.31,-3.99,-3.68,-3.50,-3.34,-3.22,
7-3.23,-3.25,-3.24,-3.18,-3.10,-3.07,-3.18,-3.41,-3.67,-4.12,
8-4.68,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.51,-4.18,
9-3.73,-3.48,-3.17,-2.96,-2.73,-2.63,-2.58,-2.59,-2.57,-2.49,
$-2.42,-2.38,-2.48,-2.62,-3.02,-3.49,-4.16,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.87,-4.50,
$-4.21,-3.90,-3.66,-3.56,-3.51,-3.51,-3.51,-3.49,-3.41,-3.34,
$-3.34,-3.47,-3.60,-3.87,-4.23,-4.59,-5.00,-5.00,-5.00,-5.00,
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.93,
$-4.51,-4.10,-3.78,-3.32,-3.03,-2.74,-2.43,-2.08,-1.83,-1.59,
$-1.29,-1.07, -.81, -.70, -.73, -.90,-1.08,-1.19,-1.35,-1.47,
$-1.57,-1.66,-1.80,-1.91,-2.04,-2.18,-2.33,-2.47,-2.61,-2.78,
$-2.97,-3.10,-3.28,-3.44,-3.63,-3.81,-3.98,-4.15,-4.32,-4.61,
$-4.71,-4.80,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.32/
 DATA(C2(I),I=1521,1575)/
1-3.24,-2.59,-2.12,-1.82,-1.57,-1.34,-1.16,-1.02, -.82, -.64,
2 -.48, -.33, -.15, -.06,  .08,  .21,  .39,  .52,  .61,  .72,
3  .85,  .96, 1.02, 1.12, 1.18, 1.21, 1.17, 1.08,  .98,  .90,
4  .97, 1.13, 1.37, 1.58, 1.74, 1.70, 1.48, 1.13,  .73,  .22,
5 -.51,-1.57,-3.48,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
6-5.00,-5.00,-5.00,-5.00,-5.00/
 C2L=C2(L)
 RETURN
 END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C3D1A (C3L,L)
C        OZONE
C     C3 LOCATION   1     V =   575    CM-1
C     C3 LOCATION  510    V =  3270 CM-1
      COMMON /C3/ C3(540)
      DATA(C3(I),I=   1, 190)/
     1-4.15,-3.51,-3.00,-2.54,-2.12,-1.76,-1.50,-1.21, -.88, -.49,
     2 -.29, -.10,  .07,  .12,  .24,  .32,  .43,  .52,  .58,  .65,
     3  .72,  .79,  .76,  .72,  .68,  .64,  .68,  .79,  .83,  .83,
     4  .80,  .78,  .68,  .56,  .49,  .42,  .34,  .26,  .14,  .02,
     5 -.14, -.35, -.51, -.74, -.88,-1.17,-1.40,-1.58,-2.11,-2.47,
     6-2.83,-3.24,-3.59,-3.94,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     7-5.00,-5.00,-5.00,-5.00,-5.00,-4.46,-4.00,-3.50,-3.14,-2.78,
     8-2.41,-2.10,-1.78,-1.49,-1.20, -.20,  .15,  .35,  .57,  .78,
     9  .95, 1.20, 1.40, 1.65, 1.80, 1.97, 2.10, 2.21, 2.31, 2.38,
     $ 2.40, 2.42, 2.58, 2.52, 2.20, 2.48, 2.54, 2.45, 2.20, 2.00,
     $ 1.20,  .95,  .92,  .90,  .90,  .89,  .90,  .92,  .94,  .95,
     $  .96,  .95,  .90,  .80,  .68,  .55,  .40,  .30,  .19,  .08,
     $ -.02, -.11, -.22, -.41, -.56, -.71, -.89,-1.03,-1.18,-1.33,
     $-1.60,-1.76,-1.90,-2.02,-2.21,-2.46,-2.59,-2.79,-3.00,-3.22,
     $-3.61,-4.16,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00/
      DATA(C3(I),I= 191, 380)/
     1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     2-5.00,-5.00,-5.00,-5.00,-4.16,-3.91,-3.66,-3.41,-3.05,-2.69,
     3-2.44,-2.19,-2.03,-1.86,-1.71,-1.56,-1.48,-1.39,-1.26,-1.13,
     4 -.97, -.81, -.65, -.48, -.35, -.22, -.14, -.06, -.02, -.09,
     5  .18, -.14,  .06,  .26, -.07, -.42, -.80, -.82, -.80, -.74,
     6 -.74, -.79, -.84, -.89, -.85, -.81, -.76, -.70  -.68, -.64,
     7 -.65, -.66, -.72, -.78, -.84, -.90,-1.02,-1.14,-1.24,-1.33,
     8-1.47,-1.61,-1.77,-1.92,-1.98,-2.04,-2.08,-2.09,-2.06,-2.03,
     9-1.98,-1.93,-1.87,-1.82,-1.76,-1.71,-1.65,-1.59,-1.51,-1.44,
     $-1.36,-1.28,-1.18,-1.08, -.98, -.88, -.78, -.69, -.59, -.49,
     $ -.37, -.25, -.18, -.10, 0.00,  .16,  .27,  .38,  .57,  .75,
     $  .93, 1.11, 1.20, 1.33, 1.44, 1.46, 1.48, 1.48, 1.64, 1.58,
     $ 1.49, 1.23,  .66,  .38, -.33, -.71, -.66, -.58, -.49, -.47,
     $ -.40, -.40, -.46, -.53, -.64, -.76, -.89,-1.01,-1.14,-1.26,
     $-1.40,-1.55,-1.69.-1.83,-1.98,-2.13,-2.28,-2.43,-2.64,-2.86,
     $-3.07,-3.28,-3.50,-3.72,-3.94,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00/
      DATA(C3(I),I= 381, 540)/
     1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,
     4-5.00,-5.00,-5.00,-4.16,-3.97,-3.77,-3.58, 3.38,-3.07,-2.75,
     5-2.44,-2.12,-1.85,-1.57,-1.30,-1.07, -.98, -.94, -.89, -.85,
     6 -.81, -.77, -.72, -.68, -.63, -.58, -.53, -.48, -.41, -.34,
     7 -.26, -.19, -.17, -.18, -.19, -.46, -.79,-1.12,-1.45,-1.75,
     8-2.38,-2.97,-3.57,-4.16,-5.00,-5.00,-5.00,-4.16,-3.90,-3.63,
     9-3.37,-3.10,-2.79,-2.47,-2.15,-1.84,-1.73,-1.63,-1.52,-1.41,
     $-1.33,-1.25,-1.17,-1.09,-1.02, -.96, -.89, -.82, -.73, -.68,
     $ -.54, -.47, -.27, -.12,  .03,  .18,  .25,  .31,  .39,  .47,
     $  .48,  .49,  .50,  .50,  .48,  .46,  .23,  .01, -.11, -.33,
     $ -.55, -.77, -.83, -.88, -.94, -.92, -.91, -.90, -.85, -.80,
     $ -.76, -.71, -.69, -.67, -.66, -.65, -.65, -.66, -.67, -.68,
     $ -.70, -.72, -.82, -.93,-1.03,-1.14,-1.24,-1.37,-1.51,-1.68,
     $-2.13,-2.57,-2.92,-3.26,-3.71,-4.16,-5.00,-5.00,-5.00,-5.00/
      C3L=C3(L)
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C4DTA
      COMMON /C4C5C8/ C4(133),C5(15),C8(102)
C        N2 CONTINUUM
C     C4 LOCATION  1    V =  2050 CM-1
C     C4 LOCATION  133  V =  2740 CM-1
      DATA(C4(I),I=   1, 114)/
     1 2.93E-04, 3.86E-04, 5.09E-04, 6.56E-04, 8.85E-04, 1.06E-03,
     2 1.31E-03, 1.73E-03, 2.27E-03, 2.73E-03, 3.36E-03, 3.95E-03,
     3 5.46E-03, 7.19E-03, 9.00E-03, 1.13E-02, 1.36E-02, 1.66E-02,
     4 1.96E-02, 2.16E-02, 2.36E-02, 2.63E-02, 2.90E-02, 3.15E-02,
     5 3.40E-02, 3.66E-02, 3.92E-02, 4.26E-02, 4.60E-02, 4.95E-02,
     6 5.30E-02, 5.65E-02, 6.00E-02, 6.30E-02, 6.60E-02, 6.89E-02,
     7 7.18E-02, 7.39E-02, 7.60E-02, 7.84E-02, 8.08E-02, 8.39E-02,
     8 8.70E-02, 9.13E-02, 9.56E-02, 1.08E-01, 1.20E-01, 1.36E-01,
     9 1.52E-01, 1.60E-01, 1.69E-01, 1.60E-01, 1.51E-01, 1.37E-01,
     $ 1.23E-01, 1.19E-01, 1.16E-01, 1.14E-01, 1.12E-01, 1.12E-01,
     $ 1.11E-01, 1.11E-01, 1.12E-01, 1.14E-01, 1.13E-01, 1.12E-01,
     $ 1.09E-01, 1.07E-01, 1.02E-01, 9.90E-02, 9.50E-02, 9.00E-02,
     $ 8.65E-02, 8.20E-02, 7.65E-02, 7.05E-02, 6.50E-02, 6.10E-02,
     $ 5.50E-02, 4.95E-02, 4.50E-02, 4.00E-02, 3.75E-02, 3.50E-02,
     $ 3.10E-02, 2.65E-02. 2.50E-02, 2.20E-02, 1.95E-02, 1.75E-02,
     $ 1.60E-02, 1.40E-02, 1.20E-02, 1.05E-02, 9.50E-03, 9.00E-03,
     $ 8.00E-03, 7.00E-03, 6.50E-03, 6.00E 03, 5.50E-03, 4.75E-03,
     $ 4.00E-03, 3.75E-03, 3.50E-03, 3.00E-03, 2.50E-03, 2.25E-03,
     $ 2.00E-03, 1.85E-03, 1.70E-03, 1.60E-03, 1.50E-03, 1.50E-03/
      DATA(C4(I),I= 115, 133)/
     1 1.54E-03, 1.50E-03, 1.47E-03, 1.34E-03, 1.25E-03, 1.06E-03,
     2 9.06E-04, 7.53E-04, 6.41E-04, 5.09E-04  4.04E-04, 3.36E-04,
     3 2.86E-04, 2.32E-04, 1.94E-04, 1.57E-04, 1.31E-04, 1-02E-04,
     4 8.07E-05/
C        4M  H2O CONTINUUM
C      C5 LOCATION  1    V =  2350   CM-1
C      C5 LOCATION  15   V =  2420   CM-1
      DATA(C5(I),I=   1,  15)/
     1 0.00,  .19,  .15,  .12,  .10,  .09,  .10,  .12,  .15,  .17,
     2  .20,  .24,  .28,  .33, 1.00/
C        OZONE U.V. + VISIBLE
C      C8 LOCATION  1    V =  13000  CM-1
C      C8 LOCATION  56   V =  24200  CM-1
C        DV = 200  CM-1
C      C8 LOCATION  57   V =  27500  CM-1
C      C8 LOCATION  102  V =  50000  CM-1
C        DV = 500  CM-1
      DATA(C8(I),I=   1, 102)/
     1 4.50E-03, 8.00E-03, 1.07E-02, 1.10E-02, 1.27E-02, 1.71E-02,
     2 2.00E-02, 2.45E-02, 3.07E-02, 3.84E-02, 4.78E-02, 5.67E-02,
     3 6.54E-02, 7.62E-02, 9.15E-02, 1.00E-01, 1.09E-01, 1.20E-01,
     4 1.28E-01, 1.12E-01, 1.11E-01, 1.16E-01, 1.19E-01, 1.13E-01,
     5 1.03E-01, 9.24E-02, 8.28E-02, 7.57E-02, 7.07E-02, 6.58E-02,
     6 5.56E-02, 4.77E-02, 4.06E-02, 3.87E-02, 3.82E-02, 2.94E-02,
     7 2.09E-02, 1.80E-02, 1.91E-02, 1,66E-02, 1.17E-02, 7.70E-03,
     8 6.10E-03, 8.50E-03, 6.10E-03, 3.70E-03, 3.20E-03, 3.10E-03,
     9 2.55E-03, 1.98E-03, 1.40E-03, 8.25E-04, 2.50E-04, 0.       ,
     $ 0.       , 0.       , 5.65E-04, 2.04E-03, 7.35E-03, 2.03E-02.
     $ 4.98E-02, 1.18E-01, 2.46E-01, 5.18E-01, 1.02E+00, 1.95E+00,
     $ 3.79E+00, 6.65E+00, 1.24E+01, 2.20E+01, 3.67E+01, 5.95E+01,
     $ 8.50E+01. 1.26E+02, 1.68E+02, 2.06E+02, 2.42E+02, 2.71E+02,
     $ 2.91E+02, 3.02E+02, 3.03E+02, 2.94E+02, 2.77E+02, 2.54E+02,
     $ 2.26E+02, 1.96E+02, 1.68E+02, 1.44E+02, 1.17E+02, 9.75E+01,
     $ 7.65E+01, 6.04E+01, 4.62E+01, 3.46E+01, 2.52E+01, 2.00E+01,
     $ 1.57E+01, 1.20E+01, 1.00E+01, 8.80E+00, 8.30E+00, 8.60E+00/
      RETURN
      END
```

Table A2. Description of LOWTRAN Subroutines

LOWEM	Main driver program. Reads control cards.
MDTA	Contains the data for the six model atmospheres and HNO_3 profile.
NSMDL	For user defined model atmospheres or aerosols.
HPROF	Sets up horizontal profiles of attenuator densities in LOWTRAN units.
AERPRF	Sets up appropriate aerosol horizontal profiles for model selected.
PRFDTA	Contains the different aerosol model vertical distributions.
GEO	Calculates the absorber amounts along the atmospheric slant path.
ANGL	Calculates the initial zenith angle for the slant path when H1, H2 and BETA are given.
POINT	Computes mean refractive index above and below a given altitude and finds equivalent absorber densities at the altitude.
EXABIN	Loads the aerosol extinction and absorption coefficients for the appropriate models and boundary layer relative humidity.
EXTDTA	Contains all the aerosol attenuation coefficients.
PATH	For radiance calculations, saves cumulative absorber amounts along slant path.
TRANS	Calculates transmittances and radiances for slant path.
TRFN	Contains transmittance functions.
AEREXT	Interpolates aerosol attenuation coefficients for values at wavenumber ν.
HNO3	Determines nitric acid absorption coefficient at ν.
C1DTA	Contains water vapor absorption coefficients.
C2DTA	Contains uniformly mixed gases absorption coefficients.
C3DTA	Contains IR ozone absorption coefficients.
C4DTA	Contains absorption data for nitrogen continuum, 4-μm water continuum and ozone UV and visible data.

Appendix B

LOWTRAN Symbols and Definitions

ABSC	Aerosol absorption coefficient
ALAM	Wavelength (μm)
ANGLE	Input zenith angle (degrees)
AVW	Average wavelength used in refractive index expression
BET	Angle subtended at the earth's center as path traverses adjacent levels
BETA	Total angle subtended by path at earth's center
CA	Conversion factor from degrees to radians
CO	Wavelength dependent coefficient used in refractive index expression
CW	Wavelength dependent coefficient used in refractive index expression
DUMMY	Used when IHAZE = 7
DV	Wavenumber increment at which transmittance is calculated
E(K)	Equivalent absorber amounts per km at height H1
EH(1, I)	Equivalent absorber amount per km for H_2O at level Z(I)
EH(2, I)	Equivalent absorber amount per km for CO_2 + N_2O etc. at level Z(I)
EH(3, I)	Equivalent absorber amount per km for O_3 at level Z(I)
EH(4, I)	Equivalent absorber amount per km for N_2 at level Z(I)
EH(5, I)	Equivalent absorber amount per km for H_2O continuum at level Z(I), (10 μm)

EH(6, I)	Equivalent absorber amount per km for molecular scattering at level Z(I)
EH(7, I)	Equivalent absorber amount per km for aerosol 1 (0 to 2 km) at the level Z(I)
EH(8, I)	Equivalent absorber amount per km for ozone (UV and visible) at level Z(I)
EH(9, I)	Mean refractive index of layer above level Z(I)
EH(10, I)	Equivalent absorber amount per km for H_2O continuum at level Z(I), (4 μm)
EH(11, I)	Equivalent absorber amount per km for nitric acid at level Z(I)
EH(12, I)	Equivalent absorber amount per km for aerosol 2 (2 to 10 km region) at the level Z(I)
EH(13, I)	Equivalent absorber amount per km for aerosol 3 (10 to 30 km) at the level Z(I)
EH(14, I)	Equivalent absorber amount per km for aerosol 4 (30 to 100 km) at the level Z(I)
EH(15, I)	Relative humidity * EH(7, I)
EXTC	Aerosol extinction coefficient
H1	Initial altitude (km)
H2	Final altitude (km)
HMIN	Minimum altitude of path trajectory (km)
HMIX(I)	Nitric acid volume mixing ratio (times 1.0 E+09) at the level Z(I)
HSTOR(I)	Interpolated nitric acid volume mixing ratios
HZ(I)	Hollerith titles for visibility
I	Running integer used as altitude (level) indicator and frequency indicator
ICH	Array used to select the correct aerosol extinction/absorption coefficients from EXABIN
IEMISS	Input control parameter determining mode of program execution (=0 for transmittance, =1 for radiance mode)
IFIND	Indicator for using subroutine ANGL
IHAZE	Boundary layer aerosol model parameter (0 to 2 km)
IJ	Running integer used as layer indicator along the atmospheric path
IKLO	Lower limit of layer loop (=1)
IKMAX	Upper limit of layer loop
IL	Integer indicator used to determine if the atmospheric path intersects the earth
IM	Parameter used when reading in a new atmospheric model
ISEASN	Parameter for seasonal dependence of aerosol profile
ITYPE	Indicator for type of atmospheric path
IVULCN	Volcanic aerosol model parameter (10 to 30 km)
IXY	Parameter for terminating program and cycling indicator

JLEXTRA	Integer indicator used when H1, H2, and HMIN are in the same layer (ITYPE=2)
JMIN	Altitude indicator for minimum height of path
JP	Print option parameter
J1	Level indicator for altitude H1
J2	Level indicator for altitude H2
KMAX	Upper limit of absorber amount loops (=15)
LEN	Parameter used for defining longest of two paths
LENST	Integer storage for parameter LEN, needed for cases run in succession
M	Integer used to identify required model atmosphere
ML	Number of levels in radiosonde data input (MODEL=7)
MODEL	Integer used to identify required model atmosphere
M1	Integer for selecting temperature altitude profile for (M=M1)
M2	Integer for selecting H_2O altitude profile for (M=M2)
M3	Integer for selecting O_3 altitude profile for (M=M3)
NL	Number of levels in model atmosphere data
NLL	Equals NL-1
NP1	Value of NP for altitude H1
P(M, I)	Pressure (mb) at level I for model atmosphere M
PI	3.141592654 that is (π)
RANGE	Path length (km)
RE	Earth radius (km)
RELHUM(I)	Relative humidity (percent) at the level Z(I)
RO	Earth radius (km) read in as input (=RE)
SEASN(ISEASN)	Hollerith titles for the season for the 2 to 30 km region
T(M, I)	Temperature (^{o}K) for model atmosphere M at level I
TBBY(IJ)	Average temperature of the IJ layer
TBOUND	Input temperature of the boundary in ^{o}K
TX(K)	Equivalent absorber amounts per km at a given altitude obtained from POINT; also transmittance values at a given wavelength for each absorber type (K = 1, KMAX)
TX(9)	Total transmittance at frequency V
TX(10)	Absorption due to aerosol only at frequency V
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
VIS	Meteorological range (km) at sea level
VSB(IHAZE)	Default meteorological range for the boundary layer aerosol model IHAZE
VULCN	Hollerith titles for the volcanic aerosol model (10 to 30 km)
VX2	Wavelength array associated with EXTC and ABCS
V1	Initial frequency for transmittance calculation, cm^{-1}
V2	Final frequency for transmittance calculation, cm^{-1}

W(K)	Total equivalent absorber amount for entire path
WH(M, I)	Water vapor density for atmospheric model M at level I (gm m^{-3})
WLAY(I, K)	The absorber amount for the species, K, and the atmospheric layer, I
WO(M, I)	Ozone density for atmospheric model M at level I (gm m^{-3})
WPATH(IJ, K)	The cumulative absorber amount of the species, K, for the IJ layer along the atmospheric slant path
X1	Earth center distance of level I
X2	Earth center distance of level I + 1
Z(I)	Altitude at level I in km

Appendix C

LOWTRAN 5 Segmented Loader Map, AFGL CDC 6600

Table C1. Listing of Segmented Load

```
LOAD MAP - SEGMENTED LOAD.                         CYBER LOADER 1.5-498      12/11/79  15.10.34.       PAGE     1

SEGLOAD DIRECTIVES.1

LOWTRAN TREE LOWEM-(NSMOL,HPROF,GEO,EXABIN,PATH,XTRANS)
LOWEM GLOBAL CARD1,CARD2,CARD3,CNTRL,MDATA
NSMOL INCLUDE NSMOL,AERPRF,PRFDTA
HPROF INCLUDE HPROF,AERPRF,PRFDTA
GEO INCLUDE GEO,POINT,ENGL
EXABIN INCLUDE EXABIN,EXTDTA
XTRANS TREE TRANS-(HNO3,C1DTA,C2DTA,C3DTA)
TRANS INCLUDE TRANS,AERPEXT,C4DTA
      END LOWEM

TREE DIAGRAM.

*LOWEM
 ?
 ?_NSMOL
 ?
 ?_HPROF
 ?
 ?_GEO
 ?
 ?_EXABIN
 ?
 ?_PATH
 ?
 ?_TRANS
    ?
    ?_HNO3
    ?
    ?_C1DTA
    ?
    ?_C2DTA
    ?
    ?_C3DTA

FWA OF THE LOAD              1025
LWA+1 OF THE LOAD           10765
CM BLANK COMMON FWA         23757

WRITTEN TO FILE        ABS

TRANSFER ADDRESS -- LOWEM          4324


-------- SEGMENT - LOWEM


PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK         ADDRESS  LENGTH   FILE        DATE     PROCSSR VER LEVEL  HARDWARE   COMMENTS

(LOWEM)          1026       6
/CARD1/     G    1034      20
/CARD2/     G    1054       7
/CARD3/     G    1063      46
/CNTRL/     G    1131      17
/MDATA/     G    1150    2033
/Q8.IO./         3203     101
/FCL.C./         3304      26
/STP.END/        3332       1
/FCL=ENT/        3333      40
/FCL.COM/        3373      14
LOWEM            3407    2304     LGO      12/11/79 FTN      4.7 476    666X I     PROGRAM    OPT=1
MDTA             5713      11     LGO      12/11/79 FTN      4.7 476    666X I     SUBROUTINEOPT=1
ACOSIN.          5724      63 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE THE INVERSE SINE OR COSINE OF X.
ALOG.            6007      63 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE COMMON AND NATURAL LOGARITHMS. OPT=ALL
ATAN.            6072      60 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE THE INVERSE TANGENT FUNCTION. OPT=ALL.
EXP.             6152      72 SL-FORTRAN  12/04/78 COMPASS  3.6 485               EXPONENTIAL FUNCTION. E TO POWER X. OPT=ALL.
EXP.MSG          6244      16 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMMON ERROR MESSAGES FOR EXPONENTIATION.
SINCOS.          6262      60 SL-FORTRAN  12/04/78 COMPASS  3.6 485               TRIGONOMETRIC SINE OR COSINE OF X. OPT=ALL.
SQRT.            6342      72 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE THE SQUARE ROOT OF X. OPT=ALL.
```

Table C1. Listing of Segmented Load (Cont.)

LOAD MAP - SEGMENTED LOAD. CYBER LOADER 1.5-498 12/11/79 15.10.34. PAGE 2

BLOCK	ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER	LEVEL	HARDWARE	COMMENTS
SYS=1ST	6374	63	SL-FORTRAN	12/04/78	COMPASS	3.6	485		MATH LIBRARY LINK TO ERROR MESSAGE PROCESSOR.
FECMSK=	6457	41	SL-FORTRAN	12/04/78	COMPASS	3.6	485		INITIALIZE CONSTANTS.
FLTIN=	6520	156	SL-FORTRAN	12/04/78	COMPASS	3.6	485		COMMON FLOATING INPUT CONVERTER.
FMTAP=	6676	357	SL-FORTRAN	12/04/78	COMPASS	3.6	485		CRACK APLIST AND FORMAT FOR KODER/KRAKER.
FCRUTL=	7255	46	SL-FORTRAN	12/04/78	COMPASS	3.6	485		FCL MISC. UTILITIES.
GETFIT=	7323	57	SL-FORTRAN	12/04/78	COMPASS	3.6	485		LOCATE AN FIT GIVEN A FILE NAME
KRAKER=	7402	375	SL-FORTRAN	12/04/78	COMPASS	3.6	485		PROCESS FORMATTED FORTRAN INPUT.
OUTC=	7777	150	SL-FORTRAN	12/04/78	COMPASS	3.6	485		FORMATTED WRITE FORTRAN RECORD.
SYSAID=	10147	1	SL-FORTRAN	12/04/78	COMPASS	3.6	485		LINK BETWEEN SYS=AID AND INITIALIZATION CODE.
SYS=AID	10150	7	SL-FORTRAN	12/04/78	COMPASS	3.6	485		AUXILIARY MATH LIBRARY LINK FOR ERRORS.
XTOY.	10157	31	SL-FORTRAN	12/04/78	COMPASS	3.6	485		REAL BASE TO REAL POWER. OPT=ALL.
Q2NTRY=	10210	0	SL-FORTRAN	12/04/78	COMPASS	3.6	485		FCL INITIALIZATION ROUTINE.
CCMIO=	10210	33	SL-FORTRAN	12/04/78	COMPASS	3.6	485		COMMON CODED I/O ROUTINES AND CONSTANTS.
ENDFIL=	10243	31	SL-FORTRAN	12/04/78	COMPASS	3.6	485		WRITE END OF LOGICAL FILE MARK.
FCL=FDL	10274	40	SL-FORTRAN	12/04/78	COMPASS	3.6	485		FCL CAPSULE LOADING
FETFST=	10334	3	SL-FORTRAN	12/04/78	COMPASS	3.6	485		CONVERTED DATA STORAGE
FLTOUT=	10337	311	SL-FORTRAN	12/04/78	COMPASS	3.6	485		COMMON FLOATING OUTPUT CODE
FORSYS=	10650	301	SL-FORTRAN	12/04/78	COMPASS	3.6	485		FORTRAN OBJECT LIBRARY UTILITIES.
INCOM=	11151	145	SL-FORTRAN	12/04/78	COMPASS	3.6	485		COMMON INPUT FORMATTING CODE
INPC=	11316	207	SL-FORTRAN	12/04/78	COMPASS	3.6	485		FORMATTED READ FORTRAN RECORD.
KODER=	11525	451	SL-FORTRAN	12/04/78	COMPASS	3.6	485		OUTPUT FORMAT INTERPRETER.
OUTCOM=	12176	154	SL-FORTRAN	12/04/78	COMPASS	3.6	485		COMMON OUTPUT CODE
SPA=	12352	11	SL-FORTRAN	12/04/78	COMPASS	3.6	485		SPA= - SUBSTITUTE PARAMETER ADDRESSES.
GOTOER=	12363	14	SL-FORTRAN	12/04/78	COMPASS	3.6	485		COMPUTED GO TO ERROR PROCESSOR.
CTL$RM	12377	433	SL-SYSLIB	09/21/79	COMPASS	3.5	476		CRM CONTROLLING ROUTINE.
CTL$WR	13032	32	SL-SYSLIB	09/21/79	COMPASS	3.5	476		CRM CONTROLLER - WEOR, REWIND
EPR$RM	13064	25	SL-SYSLIB	09/21/79	COMPASS	3.5	476		CRM ERROR PROCESSOR ENTRY
LIST$RM	13111	67	SL-SYSLIB	09/21/79	COMPASS	3.5	476		CRM - ALLOCATE SPACE FOR LIST OF FILES
CMF.ALF	13200	160	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - ALLOCATE FIXED.
CMF.CSF	13360	6	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - CHANGE SPECS FIXED.
CMM.FFA	13366	14	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - FIXED FREE ALGORITHM.
CMF.FRF	13402	35	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - FREE FIXED.
CMM.MEM	13443	7	SL-SYSLIB	11/15/79	COMPASS	3.6	498		
CMM.P	13447	205	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - RESIDENT SUBROUTINES.
CMF.SLF	13654	22	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - SHRINK AT LWA FIXED.
CPU.SYS	13676	40	SL-SYSLIB	11/15/79	COMPASS	3.5	476		PROCESS SYSTEM REQUEST.
FDL.RES	13736	211	SL-SYSLIB	11/19/79	COMPASS	3.6	498		FAST DYNAMIC LOADER RESIDENT.
FDL.MMI	14147	222	SL-SYSLIB	11/19/79	COMPASS	3.6	496		FDL MEMORY MANAGER INTERFACE.
CMF.SOA	14371	47	SL-SYSLIB	11/15/79	COMPASS	3.6	498		CMM V1.1 - SET DATA.

-------- SEGMENT - NSMDL

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK		ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER	LEVEL	HARDWARE	COMMENTS
/CARD1/	S	1034	20							
/CARD2/	S	1054	7							
/CARD3/	S	1063	46							
/CNTRL/	S	1131	17							
/MDATA/	S	1150	2033							
(NSMDL)		14440	0							
/PRFOTA/		14440	1354							
NSMDL		16014	1033	LGO	12/11/79	FTN	4.7	476	666X I	SUBROUTINEOPT=1
AERPRF		17047	243	LGO	12/11/79	FTN	4.7	476	666X I	SUBROUTINEOPT=1
PRFOTA		17312	3	LGO	12/11/79	FTN	4.7	476	666X I	SUBROUTINEOPT=1

-------- SEGMENT - MPROF

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK		ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER	LEVEL	HARDWARE	COMMENTS
/CARD1/	S	1034	20							
/CARD2/	S	1054	7							

Table C1. Listing of Segmented Load (Cont.)

```
LOAD MAP - SEGMENTED LOAD.                          CYBER LOADER 1.5-498      12/11/79  15.1..34.      PAGE    3

BLOCK          ADDRESS   LENGTH    FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

/CARD3/    S     1063       45
/CNTRL/    S     1131       17
/MDATA/    S     1150     2033
(MPROF)         14440        0
/PRFDTA/        14440     1354
MPROF           15024      641     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1
AERPOF          16665      243     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1
PRFDTA          17120        3     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1

-------- SEGMENT - GEO

PROGRAM AND BLOCK ASSIGNMENTS

BLOCK          ADDRESS   LENGTH    FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

/CARD1/    S     1034       20
/CARD2/    S     1054        7
/CARD3/    S     1063       46
/CNTRL/    S     1131       17
/MDATA/    S     1150     2033
(GEO)           14440        0
GEO             14440     1740     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1
POINT           16400      273     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1
ANGL            16673     1315     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1
TAN.            20210       76  SL-FORTRAN   12/04/78 COMPASS 1.6 485                TRIGONOMETRIC TANGENT. OPT=ALL.

-------- SEGMENT - EXABIN

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK          ADDRESS   LENGTH    FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

/CARD1/    S     1034       20
/CARD2/    S     1054        7
/CARD3/    S     1063       45
/CNTRL/    S     1131       17
/MDATA/    S     1150     2033
(EXABIN)        14440        0
/EXTDTA/        14440     3413
EXABIN          23050      372     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1
EXTDTA          23442        3     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1

-------- SEGMENT - PATH

PROGRAM AND BLOCK ASSIGNMENTS

BLOCK          ADDRESS   LENGTH    FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

/CARD1/    S     1034       20
/CARD2/    S     1054        7
/CARD3/    S     1063       45
/CNTRL/    S     1131       17
/MDATA/    S     1153     2033
(PATH)          14440        0
PATH            14440      621     LGO       12/11/79 FTN     4.7 476     666X I     SUBROUTINEOPT=1

-------- SEGMENT - TRANS
```

Table C1. Listing of Segmented Load (Cont.)

LOAD MAP - SEGMENTED LOAD. CYBER LOADER 1.5-498 12/11/79 15.10.34. PAGE 4

PROGRAM AND BLOCK ASSIGNMENTS

BLOCK		ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER LEVEL	HARDWARE	COMMENTS
/CARD1/	S	1774	27						
/CARD2/	S	1054	7						
/CARD3/	S	1063	46						
/CNTRL/	S	1131	17						
/MDATA/	S	1150	2037						
(TRANS)		14440	4						
/TREMFO/		14444	311						
/C4C5C8/		14755	372						
/AER/		15147	17						
TRANS		15357	1253	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1
AEREXT		16632	57	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1
CLCTA		16711	3	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1
TREN		16714	3	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1

-------- SEGMENT - MNO3

PROGRAM AND BLOCK ASSIGNMENTS

BLOCK	ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER LEVEL	HARDWARE	COMMENTS
(MNO3)	15717	0						
MNO3	15717	132	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1

-------- SEGMENT - C1DTA

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK	ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER LEVEL	HARDWARE	COMMENTS
(C1DTA)	16717	0						
/C1/	16717	5024						
C1DTA	23743	17	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1

-------- SEGMENT - C2DTA

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK	ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER LEVEL	HARDWARE	COMMENTS
(C2DTA)	16717	0						
/C2/	16717	3047						
C2DTA	21766	10	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1

-------- SEGMENT - C3DTA

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK	ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER LEVEL	HARDWARE	COMMENTS
(C3DTA)	16717	0						
/C3/	16717	1034						
C3DTA	17753	11	LGO	12/11/79	FTN	4.7 476	666X I	SUBROUTINEOPT=1

LOAD MAP - SEGMENTED LOAD. CYBER LOADER 1.5-498 12/11/79 15.10.34. PAGE 5

2.337 CP SECONDS 215003 CM STORAGE USED 11 TABLE MOVES

Appendix D

Water Vapor Density and Relative Humidity in LOWTRAN

LOWTRAN requires both the water vapor density, used in calculating the molecular and continuum absorption, and the relative humidity, needed for interpolating the relative humidity dependent aerosol extinction coefficients. The user is given a choice of meteorological parameters with which to specify these quantities. The possible choices are the ambient temperature and any one of the following: relative humidity, dew-point temperature, or water vapor density. From any one of these three combinations, the program will supply the missing values of water vapor density and/or relative humidity as described in the next section.

The percent relative humidity, RH, is defined as 100 times the ratio of the ambient mass mixing ratio m to the saturation mixing ratio, m_s. The mixing ratio is defined as the ratio of the density of water vapor ρ_v to the density of the dry air ρ_d.

Therefore

$$\frac{RH}{100} = \frac{m}{m_s} = \frac{\rho_v/\rho_d}{\rho_s/\rho_{ds}}$$

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where ρ_s is the saturation density of water vapor at ambient temperature and ρ_{ds} is the density of the dry air at saturation. The saturation water vapor density at a given temperature T is given by the following empirical expression.[D1]

$$\rho_s(t) = A \exp(18.9766 - 14.9595A - 2.4388A^2) \text{ gm m}^{-3}$$

where $A = T_o/(T_o + t)$, $T_o = 273.15K$, and t is in ^oC. This expression was found to give a good fit to published values of saturation water vapor density over water to better than 1 percent for temperatures between -50^oC to 50^oC.[D2]

The following section describes the equation used to supply the missing values of water vapor density and/or relative humidity.

1. Given: ambient temperature t in ^oC and relative humidity RH; find ρ_v.

$$\rho_v = \rho_s(t) \times \frac{RH}{100} \times \left[1 - \left(1 - \frac{RH}{100}\right) \frac{\rho_s(t)\, R_v\, T}{P}\right]^{-1}$$

where R_v is the gas constant for water vapor (4.6150×10^{-3} mb gm m^{-3} K^{-1}), $T = T_o + t$ and P is the total pressure in mb. If the ratio of ρ_d/ρ_{ds} were to be neglected in the equation for RH, then ρ_v is given simply by

$$\rho_v = \rho_s(t) \times \frac{RH}{100}$$

2. Given: ambient temperature t and dew-point temperature t_D, both in ^oC; find ρ_v and RH.

The dew-point temperature t_D is defined as that temperature at which the ambient water vapor pressure would just saturate the air. This condition gives

$$\rho_v = \frac{T_D}{T} \rho_s(t_D)$$

where T and T_D are the ambient and dew-point temperature in K.

The relative humidity is given by

$$\frac{RH}{100} = \frac{\rho_v}{\rho_s(t)} \frac{\rho^* - \rho_s(t)}{\rho^* - \rho_v}$$

D1. Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance From 0.25 to 28.5 Microns: Computer Code Lowtran 3, AFCRL-TR-75-0255, AD A017 734.

D2. List, R.J. (1968) Smithsonian Meteorological Tables (6th revised edition). Smithsonian Institute Press, Washington.

where $\rho^* = P/(R_V T)$.

3. Given: t and ρ_V; find RH

RH is calculated in the same way as in 2.

Appendix E

Subroutine DRYSTR

Subroutine DRYSTR, listed in Table E1, can be used in LOWTRAN to generate "dry" stratospheric water vapor profiles. The subroutine uses a constant mass mixing ratio for water vapor above 15 km based on a recent analysis of field measurement data by Penndorf.[E1] In order to use this subroutine, the user should insert a call statement in the main program (PROGRAM LOWEM) immediately after line LOW1240, as follows

```
CALL DRYSTR                                          LOW 1245
```

A message will be printed on the output file whenever this subroutine is called giving the value of the mass mixing ratio used to generate the modified water vapor profiles.

Figures E1a and E1b show the "dry" stratospheric water vapor profiles vs altitude from 0 to 100 km and expanded profiles from 0 to 30 km calculated from subroutine DRYSTR. A mass mixing ratio of 2.6 ppmm was used.

E1. Penndorf, R. (1978) Analysis of Ozone and Water Vapor Field Measurement Data, Federal Aviation Administration, Washington, D.C., Report FAA-EE-78-29.

Table E1. Listing of Subroutine DRYSTR

```
CALL DRYSTR                                                            LCM 1245

      SUBROUTINE DRYSTR
C
C     THIS SUBROUTINE REPLACES THE STRATOSPHERIC (16 KM AND ABOVE)
C     WATER VAPOR PROFILE STORED IN MDLATM WITH
C     A "DRY" WATER VAPOR PROFILE CORRESPONDING TO
C     A CONSTANT MASS MIXING RATIO OF DRYMIX (DRYMIX=2.6 PPMM
C     FROM R. PENNDORF 1978 ANALYSIS OF OZONE AND WATER VAPOR
C     FIELD MEASUREMENT DATA FAA-EE-78-29)
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MODTA/ Z(34),P(7,34),T(7,34),WF(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(5),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),FH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      DATA DRYMIX /2.6E-6/,RV /2.870E-3/
      DO 10 N=1,6
      DO 10 I=17,33
   10 WF(N,I)=DRYMIX*P(N,I)/(RV*T(N,I))
      PRINT 900,DRYMIX
  900 FORMAT(* WATER VAPOR PROFILE HAS BEEN REPLACED BY A*,/,
     X* DRY WATER VAPOR PROFILE CORRESPONDING TO A MASS MIXING RATIO OF*
     Y,1PE10.1)
      RETURN
      END
```

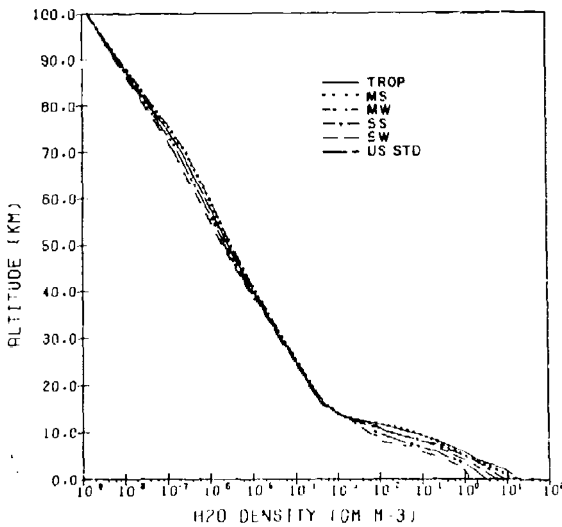

Figure E1a. Water Vapor Density Profiles vs Altitude for a "Dry" Stratosphere for the Six Model Atmospheres

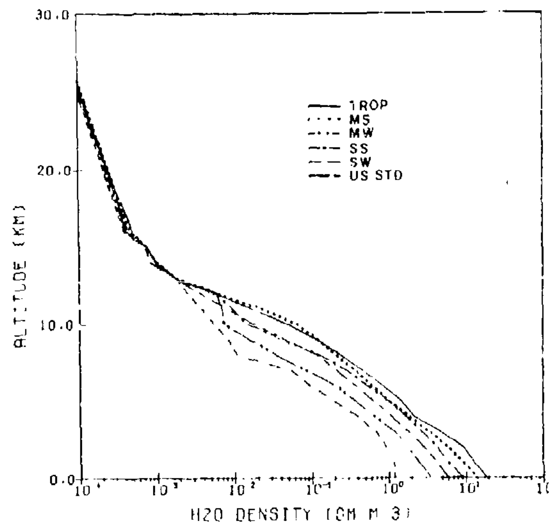

Figure E1b. Water Vapor Density Profiles vs Altitude for a "Dry" Stratosphere for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

Appendix F

Comparisons of LOWTRAN with Measurements

Comparisons of LOWTRAN with measurements from previous LOWTRAN reports[F1, F2, F3] are presented here for ready reference. These earlier comparisons used either the rural or average continental extinction coefficients for the aerosol models.

Figures F1 and F2 show transmittance comparisions of LOWTRAN with laboratory measurements of Burch et al[F4] for some important water vapor and carbon dioxide bands. It will be seen that the LOWTRAN calculations agree closely with the measured spectral transmittance.

Figure F3 shows a transmittance comparison with a sea-level measurement by Ashley et al[F5] (General Dynamics). The measurement, made with an

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F1. Selby, J.E.A., Kneizys, F.X., Chetwyn¹ Jr., J.H., and McClatchey, R.A. (1978) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4, AFGL-TR-78-0053, AD A058 643.

F2. Selby, J.E.A., Shettle, E.P., and McClatchey, R.A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B, AFGL-TR-76-0258, AD A040 701.

F3. Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255, AD A017 734.

F4. Burch, D.E., Gryvnak, D., Singleton, E.B., France, W.L., and Williams, D. (1962) Infrared Absorption by Carbon Dioxide, Water Vapor, and Minor Atmospheric Constituents, AFCRL-62-698.

F5. Ashley, G.W., Gastineau, L., and Blay, D. (1973) Private Communication.

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interferometer of $\sim 4\text{-cm}^{-1}$ resolution from 1.8 to 5.4 μm, is for a 1.3-km sea-level horizontal path.

Figure F4 shows a comparison of the calculated upward atmospheric radiance with an interferometer measurement from a balloon flight over northern Nebraska by Chaney at the University of Michigan.[F6] The measurement was taken at a float altitude of 111,700 ft. The calculated radiance used the midlatitude winter model, with a 23-km visual range, and a ground temperature of 280°K.

Figure F5 shows a comparison of an interferometer measurement made from the Nimbus 3 satellite[F7] looking down over the Gulf of Mexico with the calculated atmospheric radiance. The resolution of the interferometer was 5 cm^{-1} as compared to the 20 cm^{-1} resolution of LOWTRAN. Two theoretical models, the tropical and midlatitude summer, were used for comparison, as shown in Figure F7 and are displaced two divisions above and below the measured radiance for clarity. Both models assumed a 23-km visual range and used the temperature at 0 KM in the model atmosphere as the boundary temperature.

Figure F6 shows the comparison of atmospheric radiance as seen from space between the LOWTRAN calculation and measurements from the Nimbus 4 satellite[F8] for three different geographic locations. The spectra, obtained with a Michelson interferometer of resolution 2.8 cm^{-1}, were measured over the Sahara Desert, the Mediterranean, and the Antarctic. The calculated LOWTRAN radiances used the midlatitude winter model and a ground temperature of 320°K for the Sahara; the midlatitude winter model and a ground temperature of 285°K for the Mediterranean; and an arctic winter cold model taken from the AFCRL Handbook of Geophysics and Space Environments and a ground temperature of 190°K for the Antarctic comparison. All three calculations assumed a 23-km visual range for aerosols.

Figures F7 through F10 show comparisons of calculated and observed atmospheric spectral radiance vs wavelength in the 8- to 14-μm spectral region. The measurements were made on a balloon flight launched from Holloman AFB, New Mexico by Murcray et al,[F10] University of Denver. The instrument used for these observations was a LHe grating spectrometer, operated in the first and second order of the grating. The resolution was 0.03 μm in the 8- to 14-μm region. The data in these figures are presented as a function of altitude and as a function of zenith angle. The LOWTRAN radiance calculation used the pressure, temperature, ozone, and nitric acid profiles from the Murcray report,[F10] and the midlatitude winter water vapor profile contained in LOWTRAN.

Because of the large number of references cited above, they will not be listed here. See References, page 233.

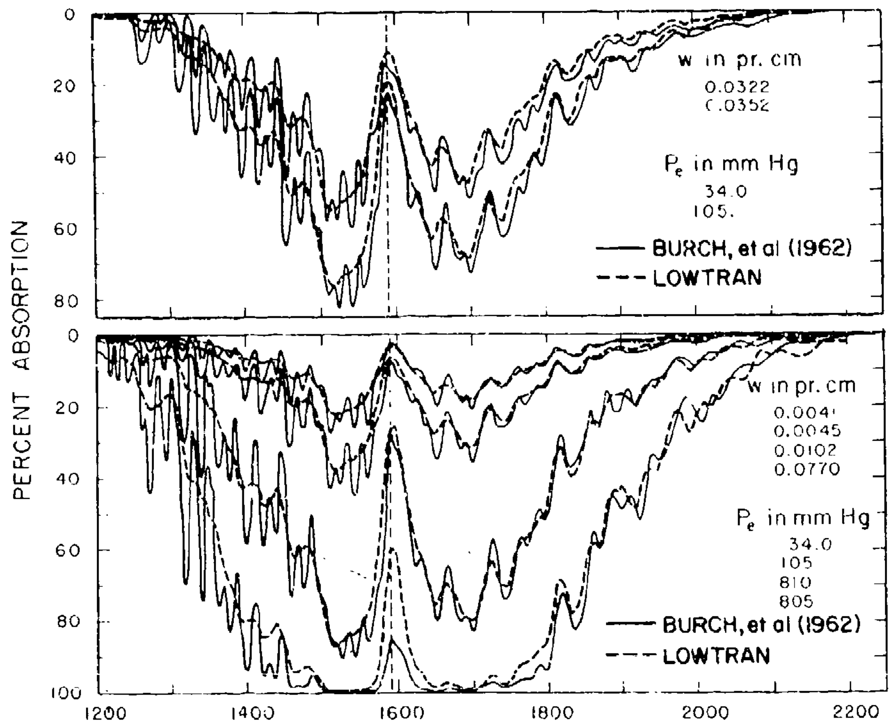

Figure F1. Representative Absorption Curves for the 6.3-μm H_2O Band

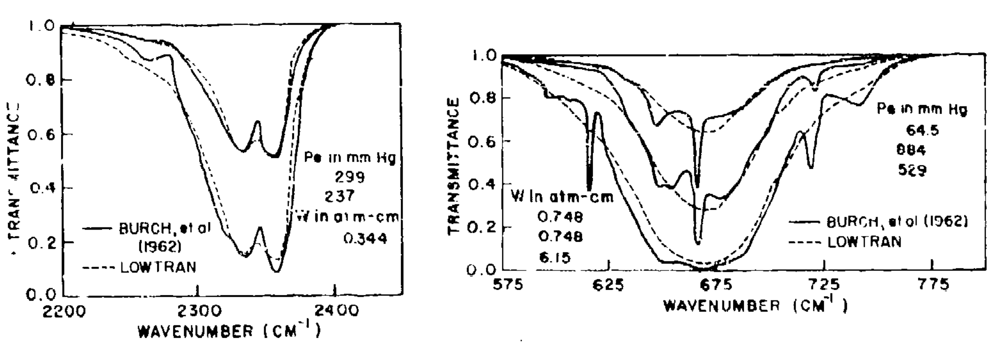

Figure F2. Comparison of LOWTRAN Calculations and Burch et al[F4] Calculations for CO_2 Bands at 4.3 μm and 15 μm

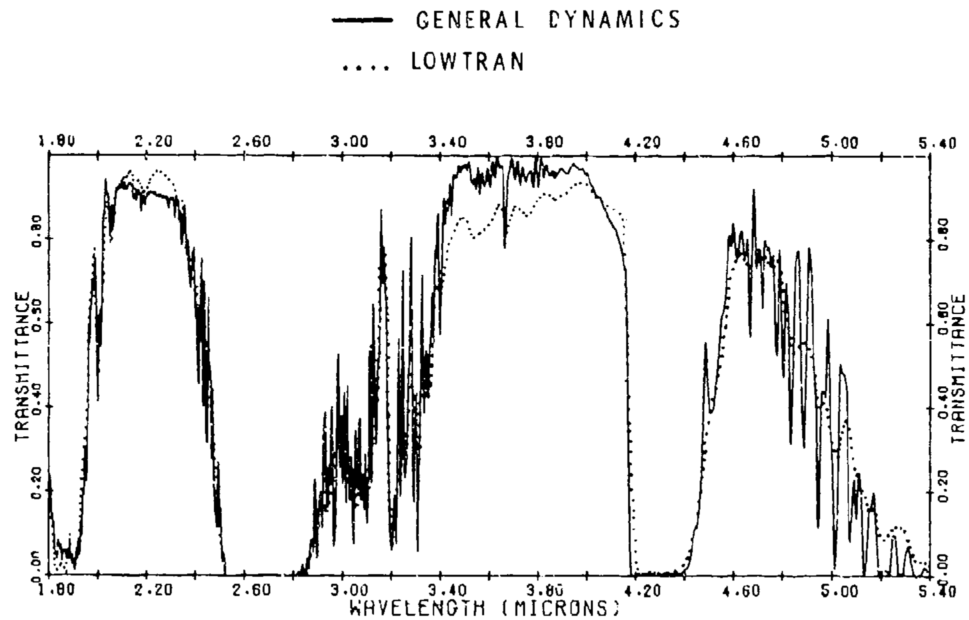

Figure F3. Comparison Between LOWTRAN and General Dynamics Measurements; Range = 1.3 km at Sea Level

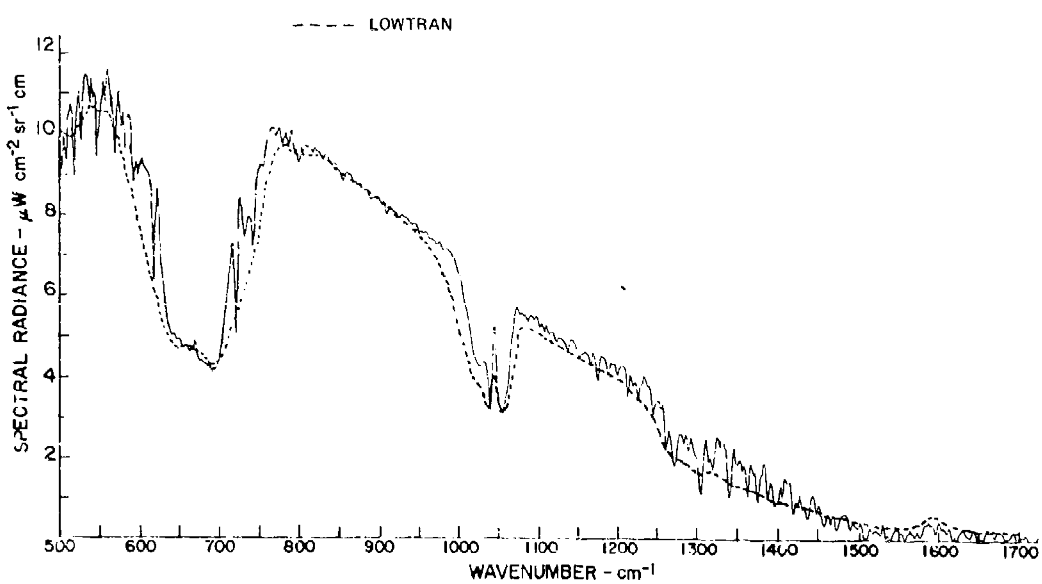

Figure F4. Comparison Between LOWTRAN Predication and University of Michigan Balloon Measurement of Atmospheric Radiance over Northern Nebraska

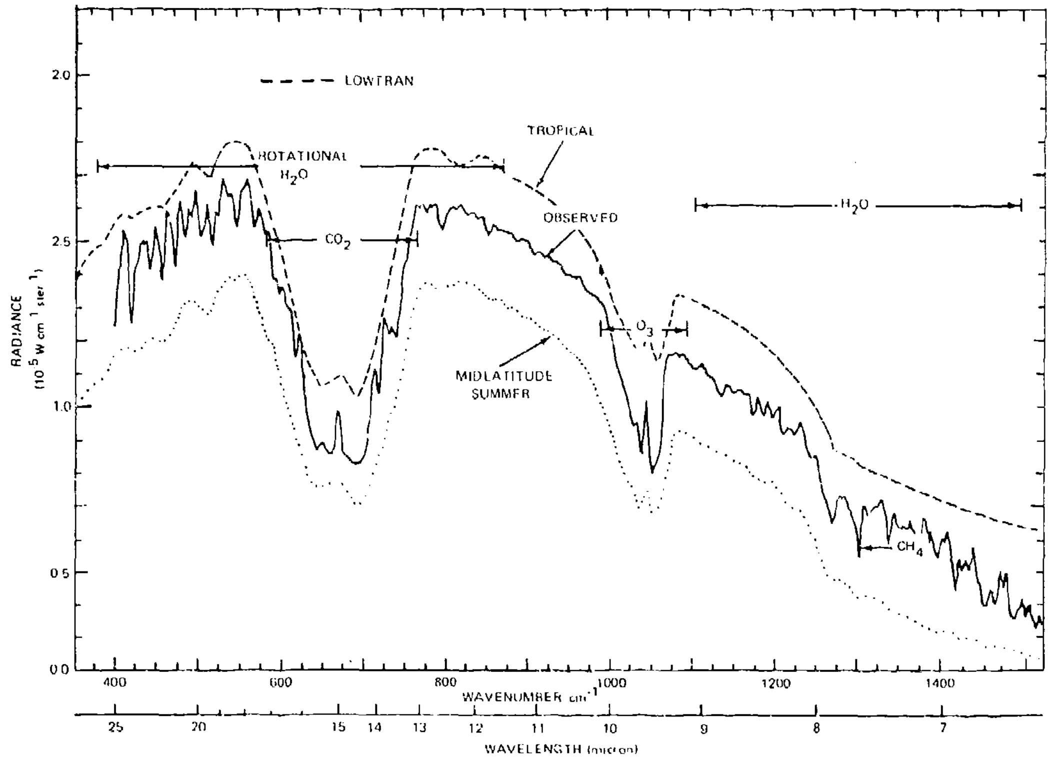

Figure F5. Comparison Between LOWTRAN Prediction and NIMBUS 3 Satellite Measurement of Atmospheric Radiance over the Gulf of Mexico

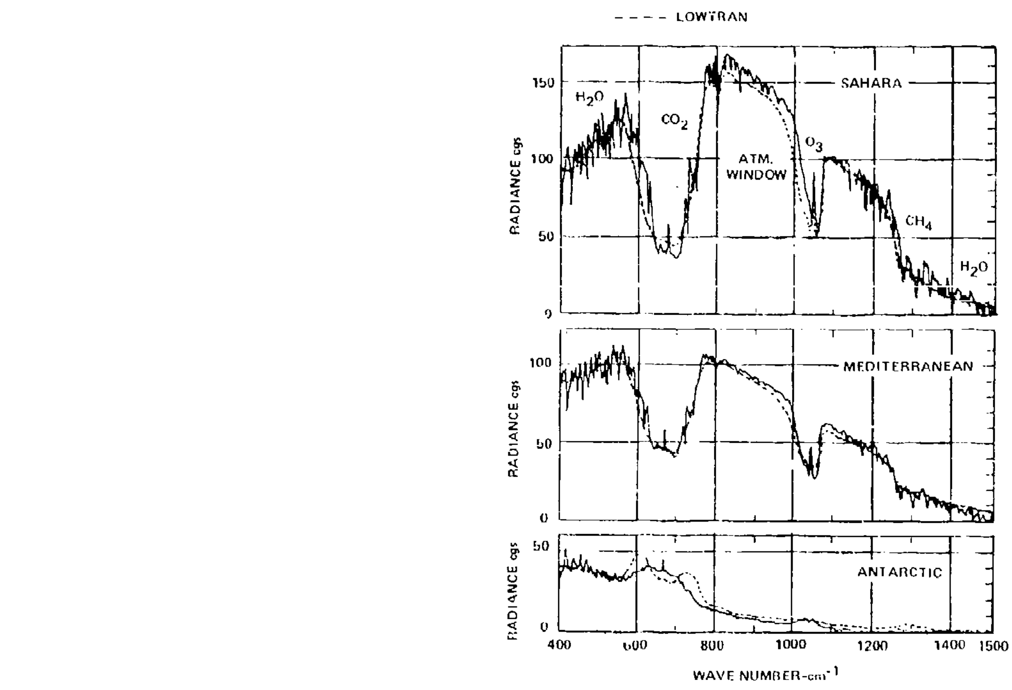

Figure F6. Comparison Between LOWTRAN Predictions and NIMBUS 4 Satellite Measurements of Atmospheric Radiance over the Sahara Desert, the Mediterranean, and the Antarctic

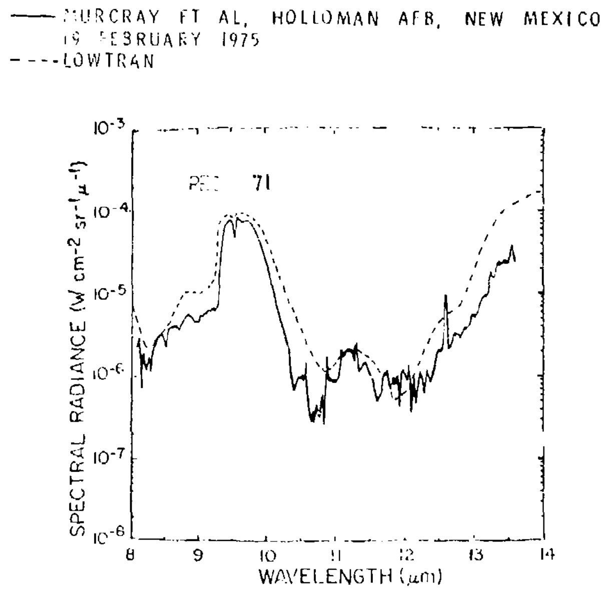

Figure F7. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 9.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

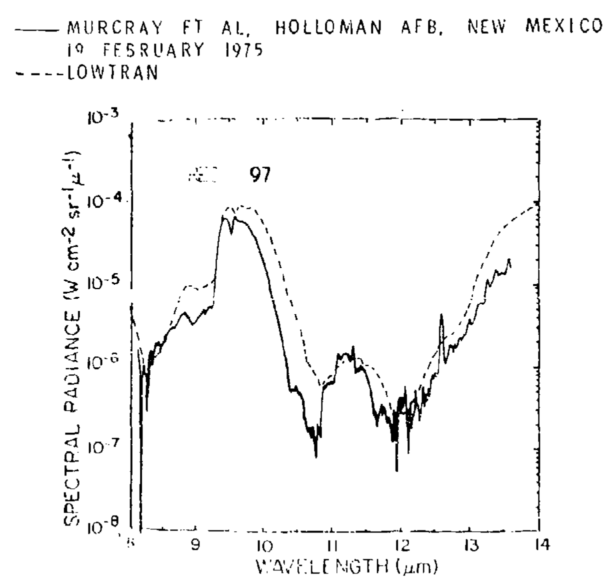

Figure F8. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 13.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

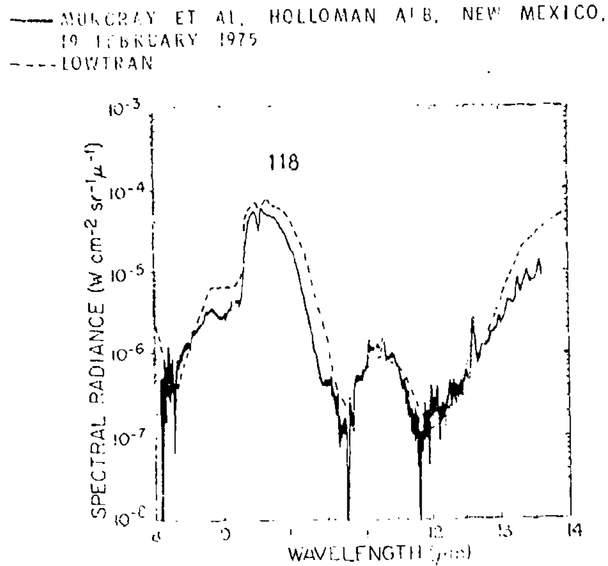

Figure F9. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 18.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

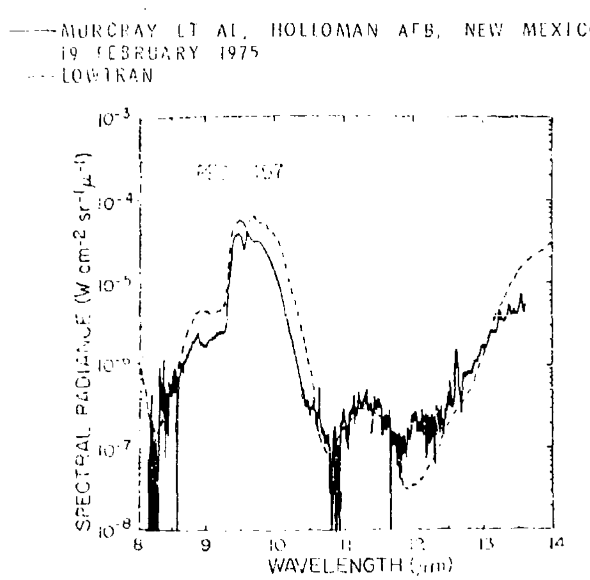

Figure F10. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 24.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

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